FOURTH ANNUAL PROGRESS REVIEW OF THE 5-YEAR NATIONAL RESEARCH AND ACTION PLAN FOR DEVELOPMENT OF MANAGEMENT AND CONTROL METHODOLOGY FOR SILVERLEAF WHITEFLY

SAN ANTONIO, TEXAS
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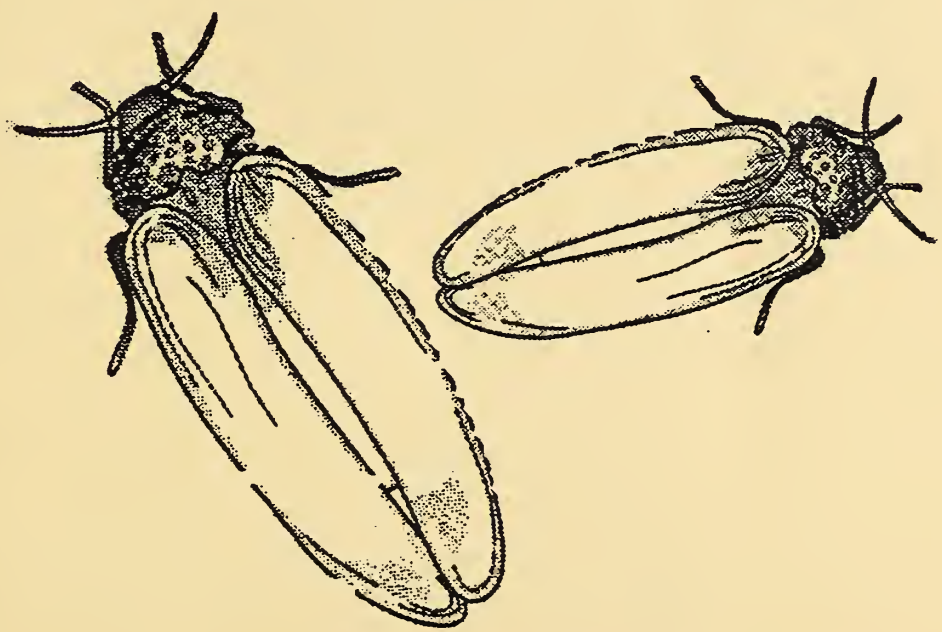
An Interagency Effort of:

USDA/Agricultural Research Service
USDA-Cooperative State Research, Education, and Extension Service
State Agricultural Experiment Stations
USDA/Animal and Plant Health Inspection Service
USDA-Extension Service
Agricultural Services and Commodities Industries

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EDITORS' COMMENTS

The multi-agency silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (formerly sweetpotato whitefly, *Bemisia tabaci* Gennadius Strain B) research and action plan is a continuing effort of federal and state agencies, and agricultural industries to develop tools for effective whitefly management. A vital facet of the plan is the annual review process. Program formats for the review focus on reports of research progress, information exchange, development of cooperative efforts, and reassessment of research priorities. Informative and productive reviews of the research and action plan were conducted in Tempe, AZ in 1993, Orlando, FL in 1994, and San Diego, CA in 1995. This publication presents a compilation of abstracts, whitefly bibliography addendum, and other information gathered at the fourth annual review, February 4-6, 1996 at San Antonio, TX. The editors appreciate the contributions of all attendees and participants. The research abstracts are intended as reports of current research and the contents remain the sole responsibility of the authors. Minor editing was done only to conform to camera-ready format requirements. Sweetpotato whitefly Strain B was described as a new species, *B. argentifolii* Bellows and Perring. In the present publication, both names appear at the discretion of the authors. The editors assume the names are synonymous. Sections of this document other than the abstracts are the combined effort of the meeting participants and other interested contributors. Tables A through F of the "5-Year National Research and Action Plan Priority Tables" have been reproduced and included in the present supplement. This is for the reader's orientation and relevance of the fourth year review to the plan in its entirety. Also included in the present publication is an addendum to the whitefly bibliography published by Butler et al. (1995) in "Silverleaf Whitefly 1995 Supplement to the 5-Year National Research and Action Plan," USDA-ARS, 1995-2, National Technical Information Service, Springfield, VA.

Editors: T. J. Henneberry, N. C. Toscano, R. M. Faust and J. R. Coppedge

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Acknowledgment:

The USDA SPW Coordinating Group, Annual Review Program Chairs, Section Chairs, Local and State Coordinators and the Technical Committee sincerely appreciate the contributions of all the participants and those who have helped in organizing the meeting. We especially thank Lisa Arth, Cindy Giorgio, and Lynn Jech for their help in assuring the success of the meeting.

CONTENTS

FOREWORD

This publication is the fourth annual report of progress of the 5-Year National Research and Action Plan for Control and Development of Management Strategies for the Sweetpotato, *Bemisia tabaci* (Gennadius) and Silverleaf whiteflies, *Bemisia argentifolii* Bellows and Perring. In 1991 and 1992, USDA agencies, State Agricultural Experiment Stations and commodity-involved industries in a cooperative effort formulated the original 5-year National Research and Action Plan that focused on developing methodology for control and management of the sweetpotato whitefly. Six high priority research and action areas were established during a series of meetings in Atlanta, GA, Reno, NV, and Houston, TX. The sweetpotato whitefly has been a worldwide economic pest for many years, but was of little concern in the United States until the late 1970's when epidemic outbreaks began to occur at sporadic intervals through the 1980's. In the late 1980's, the expanded host range involved in whitefly outbreaks, as well as biological, genetic and vector differences and the occurrence of unique adverse plant physiological disorders in some cultivated crops, led several scientists to propose the occurrence of a new sweetpotato biotype (Strain B). Subsequently, sweetpotato Strain B was described as a new species *B. argentifolii* Bellows and Perring, and renamed the silverleaf whitefly. Silverleaf whitefly terminology has not been formally accepted as a common name by the Entomological Society of America's committee on common names of insects. However, repetitive use of the name within the scientific and agricultural community prompted the USDA coordinating group to retitle the 5-year plan substituting silverleaf whitefly for sweetpotato whitefly in its 1994 report and subsequent reports of annual progress.

The transition from sweetpotato to silverleaf whitefly dominated agricultural systems in Arizona, California, Texas and Florida has not been clearly defined, but appears to have occurred during the mid to late 1980's. Economic losses from silverleaf whitefly have involved cotton and a wide range of ornamentals and vegetable crops. Conservative estimates suggested that in 1991 and 1992 losses in the agricultural communities exceeded $200 and $500 million, respectively. Crop yield losses attributable to silverleaf whitefly in the Imperial Valley, CA over a 4 year period (1991 to 1995) have been estimated to be about $100 million per year.

The success of the 5-Year National Research and Action Plan and the annual progress reviews in 1993, 1994, 1995 and 1996 have resulted from the combined efforts of participating Federal and State agencies and the agricultural industries. The urgent need for short-term technologies and the groundwork for long-term management have been established. Losses in agricultural communities where the silverleaf whitefly is a factor in crop and horticultural production have been reduced. Significant research progress has been made and a number of management tools adopted in crop production systems. More importantly, a huge base of new knowledge on biology, physiology, biochemistry, morphology, genetics, and other fundamentals of the silverleaf whitefly have been assessed. Long-term ecology based, socially and environmentally acceptable management systems will be drawn from this knowledge base.

USDA Sweetpotato Whitefly Research, Education and Implementation Coordinating Group (two members from ARS, two members from APHIS, two members from CSRS/SAES, and one member from ES) was formed in 1992 to coordinate the USDA interagency activities. The USDA Coordinating Group and partner State Agricultural Experiment Stations help ensure a unified effort for the plan and provide for an annual review to exchange research information, plan cooperative work, and evaluate research progress. The Coordinating Group deeply appreciates the contributions of all of the individuals who have made the progress reviews and 5-Year Research and Action Plan a successful endeavor. Special appreciation this year is accorded to T. J. Henneberry, N. C. Toscano, T. Perring, L. Arth, C. Giorgio, Annual Review Program Co-Chairs and committees, the Silverleaf Whitefly Technical Working Group, the National, State and local Coordinators, and the Program Chairs for their substantial efforts in this process. We particularly appreciate the effort of Dr. James R. Coppedge and his staff for local arrangements.

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EXECUTIVE SUMMARY

The silverleaf whitefly 5-year national research and action plan has been a focal point for coordination and cooperative research involving federal and state agencies, state agricultural experiment stations and commodity industries. It provides open lines of communication, strong research linkages and information exchange. The plan has been used as a model for similarly developed activities in other states and internationally. Much of the research information has provided tools to extension and education, and action agencies for use in whitefly management programs. Active participation and attendance of representatives from ten foreign countries has occurred at the annual plan reviews. The six high priority research areas that were developed during formulation of the plan have served as effective guidelines for orientation and direction of the research. The mandated annual reviews have effectively resulted in information exchange, analyses and restructuring of priorities and identification of research needs. The original 5-year plan in 1991 and 1992 targeted the sweetpotato whitefly as the pest of significance. With increasing study and accumulated evidence showing expanded host range, biological, genetic and vector differences and the occurrence of unique adverse plant physiological disorders occurring in some cultivated crops, several authors proposed a new sweetpotato whitefly biotype (Strain B). Strain B has been described as a new species *Bemisia argentifolii* Bellows and Perring and provisionally designated a common name of the silverleaf whitefly.

An overview of the plan progress reviews in 1993, 1994, 1995 and 1996 shows that extensive achievements have been made in all of the research priority areas. A complete effective management system for silverleaf is a goal for the future, but at present, is in the early formative stages and much of the accomplished research is being implemented in control programs. Extensive ecological, biological and fundamental research on the silverleaf whitefly and its natural enemies is revealing many additional potential components for incorporation into an ecologically-based management system. Some crop management and community-oriented farm practices are being implemented in an effort to provide overall whitefly population reduction. The extensive host range cultivated crops including wild weeds and urban ornamentals has been identified. These combine to provide spatial and temporal continuum of host biomass that provide silverleaf whitefly food, shelter and reproductive requirements throughout the year. The knowledge of these complex interrelationships of types of cultivated crops, crop growing sequences and urban community hosts have brought an awareness that the entire farm community must concern itself with whitefly population suppression programs.

Areawide community-involved approaches have emerged as having the best possible chance of success. For example, the cotton grower in a farming community must give careful consideration to the status of winter-spring cultivated crop sequences in proximity to prospective cotton planting locations. Although, low whitefly populations occur on vegetable crops such as broccoli, lettuce and cole crops during October through February and March, populations developing in early spring melons increase dramatically in April to May and high numbers move to cotton. Thus, early harvest and melon crop residue destruction and plowdown is an essential SLW management component for the cotton grower. An early and uniform cotton plant dating scheduling may escape high, early-season infestation levels. Planting upwind of infested or potentially infested cultivated crop hosts is a further precaution to managing early-season infestations. Smoothleaf cottons support lower whitefly population levels than hairy-leaf cottons. Also, short-season cotton types for early harvest and crop destruction are effective measures to reduce overall population densities in areawide farming community programs.

Water and fertilizer management are important factors in whitefly management. Although the mechanisms involved in the complex interaction of the host plant condition and whitefly population dynamics are largely unknown, populations increase dramatically when cotton plants become stressed. Thus, frequent and adequate irrigation during the season delay the occurrence of high population densities. These effects have been studied primarily in cotton production and information is much needed on other crop production systems.

Several insecticides alone or in combination have been found to provide adequate control on major cultivated crops. Particular attention must be given to good coverage, particularly to underleaf surfaces. Insecticide resistance management is a particularly important factor in control. It is important to avoid using materials in the same chemical class for extended periods. Frequent population monitoring of the adult and immature populations on leaves is critical to assess effectiveness of control strategies. Definitive economic threshold values have not been established, but high population levels cause severe defoliation and reduced yield as well as sticky cotton and significant losses in vegetable, ornamental and nursery crops. Community action programs involving research, extension, industry, growers and urban community are essential to provide the framework for whitefly population management systems.

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ANNUAL REVIEW OBJECTIVES

The annual review process has been considered a vital part of the 5-year silverleaf research and action plan. The activity promotes continuity of effort and maintains up to date research information exchange. Additionally, the plan remains open-ended and the review activities provide for modification, termination, or reduced research effort in areas of poor progress and low estimated potential for successfully providing useful information for silverleaf whitefly control and management. The review also provides for identification of new areas of research not covered in the plan and/or redirection of existing or establishment of new research priorities. The six high priority research areas and research approaches provide a focus for efforts to achieve the goals and objectives of the plan within a 5-year timeframe.

The objectives of the annual review process will be to provide (1) presentations of research progress in each research priority area of the plan, (2) provisions for intense scrutiny of research programs in relation to goals and objectives of the research approaches, (3) opportunity to discuss the significance of the research progress in relation to impact on development of technology to solve the silverleaf whitefly problem and finally, (4) for making recommendations regarding appropriateness of existing priorities and need for adjustments in the plan.

RESEARCH PROGRESS ON THE SILVERLEAF WHITEFLY 5-YEAR NATIONAL RESEARCH AND ACTION PLAN

The silverleaf whitefly (SLW) (formerly sweetpotato whitefly) national research and action plan was developed in 1991 and 1992 to provide the framework to optimize research progress and maximize return on available resources. Six high priority research areas were identified: (1) Ecology, Population Dynamics and Dispersal; (2) Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions; (3) Chemical Control; (4) Biological Control; (5) Crop Management Systems and Host Plant Resistance; and (6) Integrated Techniques, Approaches, and Philosophies. Annual progress reviews were held in Tempe, AZ on January 18-21, 1993, Orlando, FL, January 24-27, 1994, January 28-31, 1995, San Diego, CA and February 4-6, 1996, San Antonio, TX. Each year substantial progress has been reported in all of the national plan's priority areas (Table 1). Abstracts (117 in 1993, 146 in 1994, and 146 in 1995) of ongoing research show that extensive national effort is being expended to provide immediate and short-term relief from losses as a result of the Silverleaf whitefly epidemics. Importantly, the progress in developing basic and fundamental information on natural enemies, SLW biology, virus-vector relationships, host-plant interactions and population dynamics provides a firm base for the development of efficient long-term and acceptable strategies to manage populations.

Table 1. Numbers of Research Reports[a] at the 1993, 1994 and 1995 Sweetpotato Whitefly Annual Progress Reviews of the USDA 5-Year National Research and Action Plan.

Agency[c]/State	Research Priorities[b] A	B	C	D	E	F	Total
1993 Review, Tempe, AZ							
APHIS	0	1	0	1	0	1	3
ARS	7	11	19	13	7	0	57
AZ	2	3	4	1	0	1	11
CA	3	3	4	2	3	0	15
FL	2	3	2	2	2	1	12
GA	0	0	4	0	2	0	6
NY	1	0	1	1	0	0	2
OH	0	0	1	1	0	0	2
TX	1	1	2	0	2	2	8
TOTAL 1993	16	22	37	21	16	5	117

[a] From USDA 1993, 1994, 1995.

[b] A = Ecology, population dynamics and dispersal; B = Fundamental research, behavior, biochemistry, biotypes, morphology, physiology, systematics, virus diseases and vector interactions; C = Chemical control, biorationals and pesticide application technology; D = Biocontrol; E = Crop management systems and host plant resistance; F = Integrated techniques, approaches and philosophies; others (1994) = Dominican Republic, Valent, Miles, AirTech and Fermone Corps, others (1995) = Israel, Antibes, Mexico, Egypt, Mycotech, Valent, AgrEvo, Troy Biosciences.

[c] APHIS = USDA, Animal and Plant Health Inspection Service; ARS = USDA, Agricultural Research Service; ADA = Arizona Department of Agriculture; CDFA = California Department of Food and Agriculture.

Table 1 (Continued)

Agency[c]/State	Research Priorities[b] A	B	C	D	E	F	Total
1994 Review, Orlando, FL							
ADA	0	0	1	0	0	0	1
APHIS	0	0	0	3	0	0	3
ARS	7	14	13	10	5	1	50
AZ	7	4	5	4	2	3	25
CA	4	5	13	6	3	1	32
CDFA	0	0	0	2	0	0	2
FL	0	3	5	3	2	2	15
GA	0	0	1	0	0	0	1
HI	1	1	0	0	0	0	2
SC	0	1	0	0	0	0	1
TX	1	0	1	2	1	0	5
WI	0	2	0	0	0	0	2
OTHERS	1	0	4	2	0	0	7
TOTAL 1994	21	30	43	32	13	7	146
1995 Review, San Diego, CA							
APHIS	1	1	0	6	0	0	8
ARS	4	4	19	12	4	0	43
AZ, ASU	8	5	5	1	0	2	21
CA	3	7	7	7	2	4	30
CDFA	0	0	0	2	0	0	2
FL	1	2	1	4	1	0	9
GA	0	0	1	0	0	0	1
HI	0	1	0	1	0	0	2
KY	0	0	0	0	1	0	1
NM	1	0	0	0	0	0	1
TX	1	0	2	1	1	1	6
WI	0	1	1	0	0	0	2
OTHERS	0	3	6	7	2	2	20
TOTAL 1995	19	24	42	41	11	9	146

[a] From USDA 1993, 1994, 1995.

[b] A = Ecology, population dynamics and dispersal; B = Fundamental research, behavior, biochemistry, biotypes, morphology, physiology, systematics, virus diseases and vector interactions; C = Chemical control, biorationals and pesticide application technology; D = Biocontrol; E = Crop management systems and host plant resistance; F = Integrated techniques, approaches and philosophies; others (1994) = Dominican Republic, Valent, Miles, AirTech and Fermone Corps, others (1995) = Israel, Antibes, Mexico, Egypt, Mycotech, Valent, AgrEvo, Troy Biosciences.

[c] APHIS = USDA, Animal and Plant Health Inspection Service; ARS = USDA, Agricultural Research Service; ADA = Arizona Department of Agriculture; CDFA = California Department of Food and Agriculture.

The transition from SPW to SLW dominated agricultural systems in Arizona, California, Texas and Florida is not, at present, clearly defined but it appears to have occurred during the mid to late 1980's. Current economic losses from SLW infestations extend beyond cotton in the agricultural community and include losses to a wide range of ornamental and vegetable crops. Outbreaks of the SLW in California, Arizona, Texas and Florida, resulted in conservative estimates in 1991 and 1992 of losses nationally in the agricultural communities involved that exceeded $200 and $500 million, respectively. Crop yield losses attributable to SLW in the Imperial Valley, CA for 4 years (1991 to 1995) have been estimated to exceed $100 million per year. Expanding SLW infestations in 1992, 1993 and 1994 on cotton and numerous other crops in the San Joaquin Valley, CA, as well as infestations in Georgia, South Carolina and other states on cultivated crops, as well as increasing incidence of vectored plant diseases in Florida, suggest that the full extent of the problem may not yet be realized in the United States.

Some highlights of the research accomplished, in concept or specific implementation, that have helped in formulation of management strategies follow:

Ecology, Population Dynamics and Dispersal

Field surveys and ecological studies in Arizona, California, Texas and Florida have shown extensive weed, ornamental, nursery stock and cultivated crop-host-plant range that supports the continuity and population growth through inter- and intra-host movement during crop growing seasons. Low overwintering populations and host biomass suggest the potential for locating a weak link in the population dynamics that can be exploited in control strategies. Some biological factors affecting SLW dispersal have been identified and along with quantitative estimates of dispersal rates suggest the basis for development of regional crop management strategies. Several community-wide cotton programs utilizing developed information on monitoring, dispersal and uniform control action have been particularly successful in providing short-term protection from SLW losses. The information has also provided growers with an awareness of the importance of crop sequencing and consideration of wind direction and the proximity of host crops when new plantings are being established. Adult and immature SLW sampling methods have been developed and validated for cotton and melons in the field and for greenhouse crops. These methods are critical components of pest management programs and modeling efforts. Additionally, provisional action thresholds are being used for cotton and melons, and progress made in establishing relationships between populations and melon and cotton yields and quality. With experience and use, these thresholds become vital factors in decision making regarding the need for control action.

Fundamental Research

Analysis of SLW surface lipids, wax particle identification, morphological structure investigations of the SLW mouthparts and their role in feeding, virus acquisition and transmission, identification of amylase in SLW, physiological functions of water loss and oxygen consumption, and further elucidation of the complexities of the honeydew sugar components has increased our knowledge of the insect. This information is leading to an understanding of factors affecting biology, feeding and reproductive functions that may be exploited in management strategies.

The relative ability of some of the predominant honeydew sugars alone and in combination to induce stickiness in cotton lint has been demonstrated. Further, several enzymes have been shown to have promise for degrading the sugars involved in the sticky cotton phenomena and reducing the problem impact.

Results of studies to define virus-vector interactions, transmission, gemini virus identification and characterization, as well as research to define SLW physiological disorders such as squash silverleaf is placing perspective on the increasing scope of the plant disease problem in the agricultural community. Gemini virus sequencing studies in crop and weed species in Florida and Arizona have detected spread and suggested origins of gemini viruses. Preliminary studies in California suggest a new lettuce virus and a new cucurbit virus disease in California as indications of the emerging complex SLW virus-vector plant interactions. New techniques based on polymerase chain reactions are being developed to detect and identify gemini-type viruses. The increasing occurrence of SLW-vectored viruses suggests the need for further effort to provide methodology for detecting and controlling virus vectored SLW plant disease complexes.

Chemical Control, Biorationals and Pesticide Application Technology

Several insecticides and/or insecticide combinations have been identified as effective for SLW control on cotton, squash, melon, broccoli, tomatoes and lettuce. A number of biorational materials that include oils, soaps, and plant products have been shown effective for some crops and may be particularly useful in insecticide rotation systems to avoid resistance. Improved application methods are needed to obtain better coverage with ground and aerial application equipment. Lower air speeds and careful selection of spray nozzle types have been shown to reduce drift and improve spray deposition levels, and small droplet sizes have been associated with more effective SLW control.

Continuing research on insecticide resistance management, modes of insecticide action, genetics of resistance, action and economic thresholds, effects on natural enemies, frequency and timing and method of application are essential to determine the long-term role of chemical control as a component of SLW IPM systems. A highly effective and efficient yellow sticky card system has been developed for resistance monitoring. Other methods such as vial and leaf dip techniques and genetic probes are also in use. These methods need to be compared and a common base for interpretation of results developed. Initial results show resistance level differences from different geographic locations and with different insecticides. Within the United States there is some level of SLW resistance to all registered classes of insecticides. Various methods of combating resistance development such as chemical class rotation systems and chemical mixtures are being developed and show promise for delaying occurrence of resistance.

Biological Control

High levels of indigenous natural enemy activity occurs in cotton, soybean and peanut ecosystems, suggesting that natural enemy augmentation and conservation approaches may be important avenues for exploitation in SLW management. Foreign explorations have resulted in collection of numerous exotic parasite and predator species that are being considered as potential biocontrol agents. Release of some exotic parasitoid species have been accomplished with variable results, but monitoring is continuing to identify establishment and impact on SLW populations. In the case of predators, a monoclonal antibody has been developed to quantify the role of predation on SLW population regulation as well as to determine candidate predator potential. Initial results show positive predation for several indigenous predator species. Natural enemy efficacy, ecosystem compatibility, habitat adaptability and other factors are being studied to assure optimum utilization of indigenous and introduced parasites and predators. Progress in developing the potential of microbial control is also progressing rapidly with the identification of numerous indigenous and exotic pathogenic fungi attacking SLW. Strains of *Paecilomyces fumosoroseus* and *Beauveria bassiana* have been identified as promising biological control agents.

Crop Management Systems and Host Plant Resistance

Crop production inputs have been demonstrated to have measurable influence on SLW population dynamics. For example, studies with water management systems in cotton showed higher SLW populations in water-stressed cotton. Efficient water use to prevent stress in cotton and provide less desirable conditions for SLW can be an effective IPM component. Also, overhead sprinkler irrigation in melon plantings appear to adversely affect SLW population development. Row covers for SLW and other insect exclusion and reflective type materials for repelling SLW have also been shown partially effective in some cropping systems. In Florida, host-SLW interactions and potential for trap crop methodology appear promising in SLW management systems as a result of applying knowledge learned about host plant preference. Definition of the underlying basis for these crop-SLW interactions and further refinement may prove such methodology as economical and acceptable in crop management systems to minimize SLW impacts.

SLW resistance in several crop types has been identified, as well as for tomato mottle and other diseases. Resistant germplasm has been identified in peanut, melon, cotton, broccoli, collard and tomatoes. Host plant preferences for melons, cotton, broccoli and lettuce appear related to the amount of vascular tissue per unit of leaf area and the proximity of vascular bundles to leaf surfaces. Studies of this nature may provide leads to plant scientists for identifying resistant germ plasm and incorporating agronomic types.

Integrating Techniques, Approaches and Philosophies

Extension and education activities play essential roles in implementation of IPM systems. Integration of risk assessment information, spatial analysis, geographic information systems, communications networking, ecological modeling, and extension programs are continually improving our efforts to provide information to producers. An excellent SLW insecticide resistance management program developed in California has been implemented with a weekly newsletter to the grower community assessing status of chemical control effects and providing information on need to alternate insecticide chemistry types in chemical control approaches. A long-term goal of integrating resistance management, crop sequencing and host free periods, crop and weed destruction, SLW population and plant disease monitoring, other cultural controls and management options points out the need for coordination and cooperation of research, extension, education, growers, industry and the urban community.

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SECTION A: ECOLOGY, POPULATION DYNAMICS, AND DISPERSAL

Co-Chairs: David Byrne and Larry Godfrey

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): David N. Byrne and Robin J. Rathmann.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: June 1993 - December 1995.

Localized Migration by the Sweet Potato Whitefly, *Bemisia tabaci*

A better understanding of whitefly dispersal across agricultural landscapes will lead to management strategies that are less pesticide dependent. During the last nine years, various members of this laboratory have examined what we term localized migration (i.e., movement on the scale of a few kilometers) *by Bemisia tabaci*. Most importantly, we have characterized migratory flight by *B. tabaci* in the laboratory and used that information to explain the distribution of this insect in the field following migration. Most examination of insect dispersal has focused on long-range movement at higher altitudes. We recognize that there is likely a component of whitefly dispersal involving long-range movement (i.e., beyond 5 km), but our current focus is on whitefly dispersal within definable agricultural systems. We feel that these efforts will provide data that can be incorporated into local and community IPM programs.

Laboratory populations of *B. tabaci* have been shown to consist of both migratory and trivial flying morphs. The dispersal of these insects was then examined under field conditions during the years 1992 through 1995 (additionally see Isaacs and Byrne, this report). Insects were marked in a field of melons using fluorescent dust during two consecutive growing seasons. During the first growing season, passive traps used to collect live whiteflies were placed along 16 equally spaced transects radiating from the field to a distance of up to 1.0 km. Wind from the northeast consistently carried whiteflies to traps placed along transects in the southwestern quadrant because cold air drainages dictate wind direction during early morning hours in the desert Southwest. For this reason, during the second season traps were laid out over fallow ground in a rectangular grid extending 2.7 km to the southwest of the marked field. If dispersal from the marked field was entirely passive, patterns could have been described using a diffusion model. Statistical examination of the data, however, demonstrated that the distribution on all days was patchy. Geostatistical techniques were used to describe the observed patchiness. Traps in the immediate vicinity of the marked field consistently caught more whiteflies than the daily median. Large numbers were also collected from near the periphery of the grid. Whiteflies were far less prevalent in the grid's center. As a result, the distribution of captured whiteflies can be described as bimodal. These patterns confirm behavior observed in the laboratory, i.e., a portion of the population consists of trivial fliers that do not engage in migration and are consequently captured in traps near the marked field. Another portion is initially attracted to cues associated with skylight, ignoring cues provided by the ground (vegetative), and fly for a period of time before landing in distant traps. During both years movement of whiteflies out of the marked field had an exaggerated directional component on 13 of 14 days due to the wind aided nature of this dispersal.

Investigator's Name(s): L.D. Godfrey[1], P.B. Goodell[2], C.G. Summers[3], W.J. Bentley[4], T. Prather[2], R. Coviello[5], T.M. Perring[6], and T.S. Bellows[6].

Affiliation & Location: [1]Entomology Department, University of California-Davis; [2]Statewide Integrated Pest Management Project, University of California, Kearney Agricultural Center; [3]Entomology Department, University of California-Davis, Kearney Agricultural Center; [4]Cooperative Extension, University of California, Bakersfield, CA; [5]Cooperative Extension, University of California, Fresno, CA; [6]Entomology Department, University of California-Riverside.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1 January 1995 - 31 December 1995.

Seasonal Dynamics of Silverleaf Whitefly on Crop and Weed Hosts in the San Joaquin Valley

Populations of silverleaf whitefly (SWF) were sampled on crop and weed hosts within twelve sample sites (36 sq. mi. each) in Kern, Kings, Tulare, Fresno, and Merced counties in the San Joaquin Valley (SJV) of California. This effort represented the third and final year of research on this project within these areas. Within each sample site, three locations of every potential SWF host plants, including crop, weed, and a limited number of ornamental plants, were sampled every 2 weeks; SWF nymphs (primarily third instars) were counted for 10 minutes during a visual examination of foliage.

Field populations of the silverleaf whitefly were first found in the SJV in 1992. The project began in 1993. Silverleaf whitefly populations in 1995 were at much lower densities than in 1994 and, in many ways, populations were more similar to the 1993 levels. Highest densities were found in the two southernmost sample areas (southern/central Kern County) and in areas on the eastern edge of the SJV. For example, SWF populations in the Arvin/Lamont sample area (central Kern County) were first found on melons on 1 June 1995 compared with 3 May 1994. Densities increased to ~500 nymphs per 10-minute search in 1995 compared with ~7500 nymphs per 10-minute search in 1994. Correspondingly, SWF densities on cotton were first found in late July and remained below 1993-94 levels; densities in 1995 peaked at ~150 nymphs per 10-minute search (except for higher densities on cotton regrowth). In the Mettler/Maricopa area (southern Kern County), SWF nymphs were first found on melons and cotton in mid-July 1995. The host plant sequence was melons, acala cotton, pima cotton, fall melons, weeds, carrots, lettuce, alfalfa, and citrus. Tomatoes, peppers, and sugarbeets were also grown in this area, but were not found to be infested in 1995; however, tomatoes and peppers were SWF host plants in 1994. About 10 weed species were commonly infested with *Datura* spp. (tolguacha and jimsonweed), *Abutilon* sp. (velvetleaf), and *Malva* spp. (mallow) having the highest densities. The occurrence of SWF on broadleaf weeds, alfalfa, and carrots during the fall was common to many search areas. Weeds, citrus, and cole crops (in the areas grown) appear to be important overwintering SWF host plants. SWF densities on citrus were low, but consistently occurred during the winter.

Several possible reasons exist to explain why SWF densities were lower in 1995 than in 1994. The spring weather was not conducive to whitefly population development or to the planting of key spring host crops for SWF. Degree-day accumulation (1 March to 30 June) was 15-20% lower in 1995 than in 1994. Precipitation (1 March to 30 June) in 1995 was nearly twice that of 1994 in terms of amount and frequency of occurrence. These environmental conditions also delayed the planting of spring melons in many areas. Secondly, the high incidence of insecticide use in cotton in 1995 for lygus, aphid, and mite controls may have also "controlled" SWF. The use of Provado for lygus bugs and aphids probably exasperated the effect. Finally, the high cotton aphid and spider mite populations in cotton may have inhibited SWF population buildup on this crop.

In summary, SWF were found in all 12 of our sample sites. In 1995, SWF seasonal dynamics closely mirrored those in 1993 and population densities were lower and occurred later than in 1994. In 1995, some crop damage occurred to fall crops (melons, cole crops, etc.), but crop damage during the spring/summer was minimal.

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Affiliation & Location: [1]Entomology Department, University of California-Davis; [2]Statewide Integrated Pest Management Project, University of California, Kearney Agricultural Center.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1 January 1995 - 31 December 1995.

Sticky Trap Sampling of Silverleaf Whitefly Adults in the San Joaquin Valley

Three transects of yellow sticky traps (3 x 3 inches) were placed east to west across the southern, south- central, and central San Joaquin Valley (SJV). These lines were located in central Kern County, northern Kern County, and northern Tulare/Kings/southern Fresno Counties. Traps were placed every 1-2 miles and monitored for silverleaf whitefly (SWF) adults at ~2 weeks intervals. A 24-hour collection period was used. This is the second year of this project. First occurrence and peak occurrence of SWF adults were 7 July and 15 Sept. (southern SJV transect), 22 July and 27 Oct. (south-central SJV transect) and 2 August and 8 Nov. (central SJV transect). The dates of peak occurrence in 1994 were 16 Sept. (southern SJV transect), 1 Oct. (south-central SJV transect) and 20 Oct. (central SJV transect). Therefore, populations were delayed by 2-3 weeks in 1995 compared with 1994, especially in the northern-most transects. During the period of peak flight occurrence in 1995, 95, 79, and 51% of the traps for the southern, south-central, and central SJV transects, respectively, had SWF adults. In 1994, 100% of the traps had some SWF adults for the southern and south-central SJV transects and 74% had SWF adults for the central SJV transect. From these data, SWF adults were not as widely distributed in the SJV in 1995 as in 1994. From our observations, the timing and distribution of SWF adults from the sticky traps appeared to correspond well with SWF population dynamics in nearby fields.

Population densities were generally highest along the southern transect and on the eastern side of the SJV for the other two transects; however, densities were lower than in 1994. Populations in 1994 reached nearly 2000 SWF adults per trap per 24 hour period on some traps compared with ~1000 SWF adults per trap per 24 hour period in 1995.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: June - July 1995.

Distribution of Whitefly Life-stages on Cantaloupe

Cantaloupe vines were sampled from 20 plots in Parker Arizona. Parasites had been released at 4 densities in these plots (5 replicates per release rate). For each of 7 weeks (from 14 June-24 July), two entire cantaloupe vines were collected in each plot. The leaves were marked with the position they occupied on the vine (with the terminal leaf being # 1). The numbers of whitefly eggs, whitefly nymphs, whitefly pupae, whitefly exuviae, immature parasites, and parasite exuviae in one leaf disk per leaf were recorded. We then calculated the percentage of the total number of each life stage that occurred at each leaf position. Preliminary results indicate that leaf number 4 contained the highest percentage of whitefly eggs, and most nymphs, pupae, and exuviae were found on leaves 6, 10, and 11 respectively. However, the life stages were found over a relatively wide range of leaves (1-16 for eggs, 1-18 for nymphs, 1-22 for pupae, and 2-28 for whitefly exuviae). Both immature parasites (large larvae and pupae) and parasite exuviae were found on leaves 3-33, however the peak percentage of immatures occurred on leaf 13 and the peak percentage of exuviae occurred on leaf 14.

Investigator's Name(s): Rufus Isaacs and David N. Byrne.

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: January 1995 - November 1995.

Testing the hypothesis that flight behavior of *Bemisia tabaci* is influenced by host plant water stress

An experiment was conducted in a greenhouse to determine the impact of plant water stress on the subsequent flight behavior of whiteflies that had developed on these plants. We reared cohorts of *Bemisia tabaci* on melon plants (*Cucumis melo*, cv. Top Mark) to which different amounts of water were provided each day, creating stressed and non-stressed conditions for the plants. Leaf water potential (Ψ) was measured throughout the experiment using a psychrometer. Insects developed from eggs to adults on the plants and their flight behavior was tested in a vertical flight chamber when adults were 3 d old. We also recorded take-off, flight duration and rates of climb on video for each insect. After each assay, insects were weighed and sexed.

Water stress treatments had a significant impact on melon growth. For example, mean final plant length was 17.6 cm under water stressed conditions and 38.3 cm when there was no stress ($P<0.01$). Water stressed plants also produced fewer leaves and these were smaller. Measurements of Ψ showed that there was no difference in leaf water potential between treatments before dawn (5.3 vs. 5.9 bar, $P>0.05$). At 1 pm, there was a highly significant ($P<0.001$) difference between the Ψ in melons with water stress (13.8 bar) and that in non-stressed plants with ample water (7.5 bar).

Water stress greatly affected plant growth, but it had no significant impact on the weight of insects which developed on the plants. Mean weights were 22.45 g and 22.40 g for males, and 52.22 g and 52.23 g for females on stressed and non-stressed plants, respectively. Although plant water stress had no effect on adult weights, peak adult emergence was delayed by approximately 1d by feeding on the water stressed melons. In flight assays, females were more likely to take off towards the overhead white light than males, but water stress had no significant effect on this behavior. Speeds of ascent toward the overhead white light were greatest when they had developed on plants with water stress. In contrast, plant water stress had no significant effect on the speed of ascent of female *B. tabaci*. Water stress also had no significant effect on flight duration for male or female *B. tabaci*.

To better understand the dynamics of the interaction between plant quality and flight behavior, honeydew was measured and collected for 24 h from adult whiteflies on these plants. After this, phloem sap samples were taken from the same leaves on which the insects had been feeding. We found that whiteflies excreted half as much honeydew in 24 h on the water stressed plants than on those without water stress. This indicates that water stress had a negative impact on feeding rates. It is possible that the different volumes of phloem sap ingested by *B. tabaci* on plants with different levels of water stress resulted in the insects metabolizing a similar quantity of nutrients, explaining the insects' similar weights. This could be due to the plants with water stress having phloem sap that is more concentrated and therefore more nutritionally suitable. To test this hypothesis, phloem and honeydew samples from this experiment are currently being analyzed for their amino acid and carbohydrate content.

Previous research in this laboratory has demonstrated that leaf age has a significant impact on migratory flight behavior, with long duration flights being more prevalent in insects developing on older leaves. The lack of behavioral response to leaf water stress reported above may indicate that whiteflies are sensitive to the duration and nature of leaf quality deterioration, and that they are able to compensate for temporary reductions in food quality.

Investigator's Name(s): S.E. Naranjo[1], C.C. Chu[1], P.C. Ellsworth[2], T.J. Henneberry[1], R.L. Nichols[3], D.G. Riley[4], N.C. Toscano[5], T.F. Watson[2].

Affiliation & Location: [1]USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ; [2]Entomology Department, University of Arizona, Tucson, AZ; [3]Cotton Incorporated, Raleigh, NC; [4]Texas Agricultural Experiment Station, Weslaco, TX; [5]Entomology Dept., University of California, Riverside, CA.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: March 1994 - October 1995.

Action Thresholds for *Bemisia* in Cotton: Results from a Multi-Site Study

A regional, two-year project sponsored by Cotton Incorporated and the Arizona Cotton Growers was initiated in 1994 to determine action thresholds for adult whiteflies in cotton. The study involved sites in Maricopa and Yuma, Arizona, Bakersfield and Brawley, California, and Weslaco, Texas.

Experimental Protocols: Whitefly populations were treated with a standard tank-mix application of fenpropathrin plus acephate at (0.1 + 0.5 lb AI.)/acre in 20 gallons/acre by ground equipment whenever whitefly populations reached or exceeded 2.5, 5, 10, or 20 adults per leaf. Insecticide treatments were continued through defoliation up to harvest. Untreated plots served as a reference. All treatments were replicated five times in a latin square design. Individual plots were ca. eight 40-inch rows by 50 feet. Whitefly adults, nymphs, and eggs were counted weekly commencing 30 days following planting. All plots were harvested and lint yields determined. Samples of lint were tested with the thermodetector.

1994 Results: Results differed among locations in response to differing infestations of whitefly. In general, there were few differences in whitefly populations among action thresholds of 2.5, 5 and 10 adults/leaf. These treatments reduced populations below those in plots treated at 20 adults/leaf and in cases of heavy populations, substantially below those of non-treated plots. The number of insecticide treatments increased with the use of lower thresholds. As few as 2 treatments were needed at 2.5/leaf at Bakersfield, CA and as many as 8 were needed for this threshold in Maricopa, AZ. Twelve applications were made at Brawley, CA at this lowest threshold, however, there were some deviations from protocols at this site. No treatments were made at 20 adults/leaf in Bakersfield, CA or Weslaco, TX. Cotton yields were reduced below optimum production at Brawley, CA and Maricopa, AZ and there were no differences among 2.5, 5 and 10 adults/leaf at these sites. Yields did not differ among any treatments at Bakersfield, Yuma or Weslaco. There was no general relationship between the thermodetector ratings and threshold levels. None of the treatments at Weslaco or Maricopa were rated as sticky, while all the treatments at the other three sites were rated as having light to heavy stickiness. Rain in September may have affected stickiness results in Maricopa, AZ.

1995 Results: In comparison with 1994, whitefly populations were generally higher in 1995, with the exception that no whiteflies were present at the Bakersfield, CA site during the months of the test. As in 1994, there were generally few differences in whitefly populations among action thresholds of 2.5, 5 and 10 adults/leaf, but significant differences between these lower thresholds and 20 adults/leaf or the untreated controls. As few as 6 treatment were needed at 2.5 adults/leaf in Yuma, AZ and as many as 9 treatments were made at this threshold in Brawley, CA. As few as 1 (Yuma) and as many as 4 (Maricopa and Weslaco) treatments were necessary at 20 adults/leaf. Cotton yields were affected by heavy whitefly pressure and cool spring temperatures in AZ and CA, and other pest problems in Yuma and Weslaco. Again there were few differences in yield between plots treated at 2.5, 5 and 10 adults/leaf and no difference between those treated at 20 adults/leaf and the untreated controls. . There was again no general relationship between the thermodetector ratings and threshold levels. Stickiness readings did not differ among treatments at Weslaco, TX or Maricopa, AZ and all treated plots had readings < 5 (indicating non-sticky). No differences were detected in Brawley, CA between any of the treated plots and plots treated at 2.5, 5 and 10 adults/leaf were non-sticky. Stickiness data from Yuma are still pending.

Overall results suggest that there is little difference in either insect population density or plant responses to damage when insecticide treatments are initiated at 2.5, 5 or 10 adults/leaf. A simple economic analysis assuming ca. $20/A for a spray treatment and ca. $0.85/lb for lint suggests that the net return is generally highest for an action threshold of 5-10 adults/leaf. These results hold even if lint price is discounted for light to moderate levels of stickiness. Further analyses of whitefly infestation on plant growth and development are underway.

Investigator's Name(s): S.E. Naranjo and T.J. Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: April - October 1995.

Development of Sampling Methods for Estimating Cotton Lint Stickiness in the Field

Cotton stickiness has become a limiting factor in cotton production in many countries, and, at present, may be considered by the cotton industry as the most serious factor affecting cotton quality. There are several methods currently used to evaluate cotton lint stickiness, including those based on the minicard and the thermodetector. These laboratory procedures are fairly well standardized, however, there are still significant problems with variation and interpretation of the results. The variation associated with stickiness determination consists of several components, the most important of which are 1) the inconsistent implementation of the testing procedure and 2) the inherent variation in stickiness of lint samples collected from the field. The former problem may be ameliorated largely by the automated, high-speed thermodetector currently under development. The latter problem can only be addressed by the development of field sampling protocols that will ensure the collection of an adequate number of representative samples for determining stickiness. Research was conducted in 1995 to examine the distribution of sticky lint, optimize the sample unit size, and determine the number of samples needed for the precise estimation of lint stickiness.

Samples were collected on 1-4 dates at each of 5 field sites in Maricopa and Phoenix, AZ beginning about 2 weeks after the first appearance of open bolls. The frequency of chemical insecticide application was varied between sites in order to manipulate whitefly population densities and subsequent deposition of honeydew. Adult and immature whiteflies were sampled weekly at each site using standardized methods developed in previous years. Experimental sample units consisted of all open bolls on 1, 2, 5, 10, 20 or 30 consecutive plants. On a given sample date all six sample units were collected at each of five locations within each field along a diagonal transect. The time necessary to collect each sample was also recorded. Each lint sample was mixed, weighed and ginned. An aliquot from this mixed sample was then assayed twice for stickiness using the thermodetector and minicard method.

Data are currently being analyzed to partition the variance in stickiness readings into between-assays, within-location, and between-location components for each field site. Standard techniques will integrate this variance information with time measurements to help identify the optimal number of assays and the optimal sample unit size (number of plants) in relation to cost (time). The sample unit question will be further examined by modeling the mean/variance relationship for each sample unit across all sites and dates and calculating the time (cost) required to estimate stickiness with a fixed statistical precision. Above analyses should suggest the best sample unit to use, and the optimal number of samples necessary to achieve a precise estimate of stickiness. Additional analysis will be performed to establish relationships between insect density and stickiness.

Investigator's Name(s): J.C. Palumbo, A. Tonhasca, and D.N. Byrne.

Affiliation & Location: University of Arizona, Yuma Valley Agricultural Center, Yuma, AZ.

Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: 1994 - 1995.

Comparison of Relative Sampling Methods for Estimating Adult Sweetpotato Whitefly Abundance on Cantaloupes

Three sampling techniques (yellow sticky trap, visual [Leafturn], and modified vacuum [Handvac]) were compared over a 2-yr period to determine sampling reliability for estimating adult sweetpotato whitefly, *Bemisia tabaci* (Gennadius), population levels in cantaloupes, *Cucumis melo* L. In experimental plots, the three sampling methods indicated similar whitefly population trends throughout the season and all methods were highly correlated with immature densities. There was a strong correlation of Leafturn samples with Handvacs and sticky trap counts. In commercial fields however, seasonal patterns of population levels detected with sticky traps differed from the other sampling methods. Adult counts from the Leafturn procedure were more closely correlated with counts from Handvac samples than sticky traps. Estimates of adult abundance measured by Leafturn counts also provided a higher correlation with immature densities than the other methods. In general, estimates of whitefly population trends measured with the Leafturn and Handvac methods were similar in commercial fields despite differences in cultivar planted, year of the test, and insecticides use patterns. Estimates of relative sampling variation (precision) indicated that sticky traps were more efficient in some cases, but overall, precision did not differ among the sample methods. The relative net precision for adults was greater with the Leafturn and Handvac methods, which were less time consuming than the sticky trap. Comparison of sampling methods in small plot chemical trials indicated that yellow sticky traps were not reliable for estimating treatment differences. Only the Leafturn and Handvac methods detected significant differences in adult numbers between treated and untreated plots following insecticide applications.

Investigator's Name(s): Wee L. Yee[1], Nick C. Toscano[1], Chang-Chi Chu[2], Thomas J. Henneberry[3], and Robert L. Nichols[4].

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Research & Implementation Area: Section A: Ecology, Population Dynamics, and Dispersal.

Dates Covered by the Report: July - August 1995.

Photosynthesis of Cotton in Relation to Action Thresholds for Whitefly Control

Photosynthetic rates and stomatal conductances of cotton treated at different action thresholds for silverleaf whiteflies were measured on 12 days from July to August 1995 in Brawley in the Imperial Valley, CA, using a LI-6200 portable photosynthesis system. Action thresholds were 2.5, 5, 10, and 20 adults/leaf turn. Untreated plots were also used for comparison in a 5 x 5 Latin Square Design. Photosynthetic rates of untreated cotton leaves were significantly lower than those of 2.5, 5, and 10 adult treatment leaves on at least 9 of the 12 days ($P < 0.05$). Rate differences between 2.5, 5, and 10 adult treatments were generally not significant. Photosynthetic rates of leaves treated at 20 adults/leaf were lower than those of other treated leaves on 2 or 3 days and were higher than those on untreated leaves on 3 days ($P < 0.05$). In general, no significant differences were detected between stomatal conductances from the 2.5, 5, and 10 adult treatment leaves ($P < 0.05$), and results were similar to the pattern seen with photosynthesis. Adult, egg, and nymphal densities on untreated cotton were usually higher than those on all other treatments ($P < 0.05$), but in general no differences in densities of any stage were seen in 2.5, 5, and 10 adult treatments. Densities from the 20 adult treatment were generally not different from untreated nor from 2.5, 5, and 10 adult treatments ($P < 0.05$). Based on photosynthetic rates, stomatal conductances, and immature whitefly densities, the best action threshold on cotton in the Imperial Valley seems to be between 10 and 20 adult whiteflies/leaf.

TABLE A. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Yr. 4: Determine seasonal contribution of cultivated and wild host plants to SPW population dynamics.			
A.2 Develop efficient SPW sampling plans for research and decision making purposes.	Yr. 4: Continue testing and implementation of sampling plans in terms of reliability and efficiency, continue development of remote sensing tools.			
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Yr. 4: Perform economic analyses, evaluate economic thresholds in crops studied.			
A.4 Develop and test population models to describe and predict SPW dynamics.	Yr. 4: Validate simulation models under field conditions, analyze model behavior.			
A.5 Determine factors influencing SPW dispersal and impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems. (Combined with A.6 based on Year 1 recommendations)	Yr. 4: Examine interrelationships of crop production methods and SPW dispersal.			
A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Yr. 4: Continue as in Year 3.			

SECTION B: FUNDAMENTAL RESEARCH—BEHAVIOR, BIOCHEMISTRY, BIOTYPES, MORPHOLOGY, PHYSIOLOGY, SYSTEMATICS, VIRUS DISEASES, AND VIRUS VECTOR INTERACTIONS

Co-Chairs: Jeff Shapiro and Judith K. Brown

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): A.C. Bartlett and L.J. Lewis.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Genetic Analysis of Whitefly Populations

During the past two years we have received samples of whiteflies from investigators in Mexico, Guatemala, Venezuela, Bermuda, Puerto Rico, Brazil, Ecuador, Dominican Republic, India, Nicaragua, Chili, Spain, Germany, Israel, Zimbabwe, Pakistan, and several areas in the United States. These collections represent 50 different geographic locations or hosts. DNA was extracted from individuals in each of the collections and subjected to RAPD-PCR analysis of the genetic variability within and between the collections. RAPD patterns were examined for each of three different 10-mer primers. Each RAPD-PCR run contained three to five individuals from samples of whiteflies collected in Arizona from 1981 - 1986 to represent the "A-type" RAPD patterns, plus three to five individuals from collections made in 1994 and 1995 in a three-acre cotton field adjacent to the Western Cotton Research Laboratory to represent the "B-type" RAPD patterns along with one to five individuals of the various collections mentioned above. Samples of whiteflies from Puerto Rico, Mexico, and India contained individuals which yielded the "A-type" patterns, but this occurred only rarely. Genetic analysis of the patterns showed that most of the collections did not fall clearly within the "A" or "B" types, but rather fell in a continuous distribution of genotypes between those two extremes. We have recently acquired a new computer analysis program for RAPD data sets which will allow statistical significance statements to be made. The results of that analysis is not yet completed but, hopefully, will be ready in time for the meeting.

Investigator's Name(s): J.K. Brown[1], S.D. Wyatt[2], G.K. Banks[1], P.F. McGrath[1], A.M. Idris[1], P. Parker[3], and J. Bird[4].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1, 1995 - December 31, 1995.

DNA Sequence Database for Whitefly-Transmitted Geminiviruses from the U.S., Mexico, and the Caribbean Basin

Whitefly-transmitted (WFT) geminiviruses have become important economic constraints on production of food and fiber crops throughout the US sunbelt states (AZ, FL, TX), Mexico, the Caribbean Basin, and elsewhere throughout the world. The emergence of the WFT geminiviruses as global pathogens is directly related to increased levels of the whitefly [*Bemisia tabaci* (Genn.)] vector, worldwide, and the reasons for this phenomenon are multi-fold. In affected areas, indigenous whitefly vector populations have reached unprecedented levels due to recently implemented, year-round cropping practices and to the development of insecticide resistance in whiteflies associated with high-input cropping systems. In other areas, the recent introduction and establishment of the exotic B biotype has been a major factor, as this more fit, Old World whitefly has inadvertently displaced less aggressive, indigenous populations in many Western Hemisphere sites. Most emerging geminivirus pathogens remain unidentified and uncharacterized, and disease epidemiologies remain largely unstudied, making it impossible to determine which WFT geminiviruses should be targeted by disease control efforts. To confound the problem, at least one exotic virus of tomato has become epidemic in the Caribbean Basin, and threatens to spread throughout the region.

Our current efforts are aimed at examining the identity and distribution of predominant WFT geminiviruses in Arizona and Texas, northwestern Mexico, and the Caribbean Basin. This goal is being addressed through the establishment of a database of geminivirus coat protein gene sequences. Viral gene sequences are obtained by direct sequencing of the polymerase chain reaction (PCR) product of a conserved 550 bp region within the coat protein gene. Ultimately, sequences will be targeted within other informative regions. These sequences will be useful to establish virus relationships, and to track geminivirus quasi species for molecular epidemiological purposes. To accomplish these goals, database sequences will be used for virus identification by comparing existing with input sequences, and for predicting virus relationships, both essential components of epidemiological studies. The database sequences will also permit predictions about the potential for recombination, and/or transactivated replication among geminiviruses in mixed infections. Ultimately, the long term goals are (1) to identify the most important geminivirus pathogens for disease resistance programs, and (2) early discovery of indigenous and/or exotic viruses that may incite new disease epidemics in commercial and/or urban areas.

Investigator's Name(s): J.K. Brown, R.C. Rosell, and I. Torres-Jerez.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1, 1995 - December 31, 1995.

Morphological and Genetic Analysis of the *Bemisia tabaci* Species Complex

Morphological and genetic characters of a suite of whitefly populations are being examined to further test the proposed hypothesis that members of the taxon *Bemisia tabaci* (Genn.), including a population known as *B. argentifolii*, represent a species complex (Brown et al., 1995). Morphological studies were conducted in collaboration with Dr. P. G. Markham and I. Bedford (John Innes Centre, Norwich, UK), and 16S ribosomal mtDNA studies were done in collaboration with Dr. D. F. Frohlich (Biology Department, University of St. Thomas, Houston, TX). Field populations of *B. tabaci* used for 16S ribosomal mtDNA analysis were collected by Drs. L. Lacey and A. Kirk, USDA/ARS European Biological Control Laboratory, Montpellier, France), and were provided through the cooperation of Drs. L. Wendel, D. Vacek, J. Goolsby, and M. Ciomperlik (USDA-APHIS-PPQ Biological Control Laboratory, Mission, TX).

Morphological characters of the pupal case (N=10-30 per population) were examined by SEM: anterior submarginal setae (ASMS), anterior wax length and width, posterior wax length and width, length of dorsal setae, presence of dorsal setae 4, length of caudal setae, and length of posterior submarginal setae 5. Phylogenetic analysis (PAUP) indicate that no morphological character, or character set, is useful for distinguishing species among the seventeen *B. tabaci* populations examined. Likewise, the putative diagnostic ASMS 4 setae do not permit differentiation between populations; however, their absence was often a characteristic of Eastern versus Western populations.

Phylogenetic analysis of ribosomal 16S mtDNA sequences reliably separate whitefly populations into four predominant clusters. Three of these groups contain whiteflies of (recent) Eastern Hemisphere origin, and one group contains all populations of Western origin. The so-called 'B biotype' clusters with several populations of Middle Eastern origin, all with a demonstrated silverleaf phenotype, suggesting that the 'B biotype" it is an Old World whitefly. The other two Eastern Hemisphere clusters contain populations from either India or Sudan, respectively.

The Indian Subcontinent is the proposed center of diversity/origin for this whitefly; thus, a more complex gene pool should exist there, and/or in surrounding/adjacent areas. This latter observation supports the hypothesis that an Eastern Hemisphere site is a center of diversity, and possibly the origin, of the *B. tabaci* species complex. The lack of any reliable morphological character, or character set, that readily permits differentiation of these candidate populations adds further credence to a species complex hypothesis.

Investigator's Name(s): James S. Buckner, Dennis R. Nelson and Marcia C. Mardaus.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: 1995.

The Surface Lipids of *Bemisia argentifolii* Nymphs and Exuviae

The total surface lipid composition was determined for silverleaf whitefly (SLWF) last instar nymphs and the exuviae after adult emergence. Nymphs and exuviae were removed from cotton leaves and surface lipids were obtained by submersion in hexane for 1 min, then chloroform for 1 min. The identification, quantities and distributions of surface lipid components were determined by analyses of portions of total lipid extracts by capillary gas chromatography (CGC) and CGC-mass spectrometry (CGC-MS).

The quantity of extractable surface lipid from each SLWF exuviae was 80% greater than the amount of lipid from each nymph. This observation indicated that substantial quantities of lipid were extracted from the interior surfaces of exuviae. The surface lipid extract from nymphs was composed of wax esters (83%), long-chain aldehydes (8%), hydrocarbons (6%) and long-chain alcohols (2%). The lipid class distribution for exuviae was similar: wax esters (85%), long-chain aldehydes (8%), long-chain alcohols (4%) and hydrocarbons (3%).

The chain-length distribution for each lipid class was similar for both nymphs and exuviae. The wax esters of nymphs and exuviae were composed of even-numbered carbon compounds ranging from C_{38} to C_{64}. The major wax ester chain lengths were C_{52} (38% of the nymph wax ester fraction and 46% of the exuviae wax esters), C_{54} (21-23%), C_{50} (13%) and C_{48} (6-7%). Analyses of the wax ester fractions by CGC-MS with single ion monitoring revealed that the major acid and alcohol moieties were even-numbered carbon constituents ranging from C_{14}-C_{28} and C_{24}-C_{36}, respectively. The major constituent of the major C_{52} wax esters was dotriacontanyl icosanoate. For both nymphs and exuviae, the major aldehyde was dotriacontanal (C_{32}), with lesser amounts of C_{34}, C_{30}, C_{26} and C_{28} aldehydes. For both nymph and exuviae, the major alcohols were near equal amounts of dotriacontan-1-ol (C_{32}) and tetratriacontan-1-ol (C_{34}), with lesser amounts of C_{30} and C_{28} alcohols. The major hydrocarbons for both nymphs and exuviae were odd carbon-numbered *n*-alkanes: C_{31}, C_{33}, C_{35}, C_{27} & C_{25} in decreasing order of abundance.

These findings indicate that the major difference between the surface lipids of SLWF nymphs and exuviae is the greater quantity of lipid associated with the exuviae. The only lipid class that did not show a greater quantity of lipid from exuviae as compared to nymph was the hydrocarbons, suggesting that hydrocarbons were present only on the surface of the exuviae, whereas the wax esters, aldehydes and alcohols were present on both the surface and the interior of the exuviae. These findings on the total surface lipid composition for SLWF nymphs and their exuviae were also compared to similar analyses of surface lipid extracts of nymphs and exuviae from laboratory-reared sweetpotato whiteflies (SPWF), *Bemisia tabaci*. No significant differences between SLWF and SPWF were observed for either the distribution of wax esters, aldehydes, alcohols and hydrocarbons or the chain-length distribution for each of the lipid classes.

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Affiliation & Location: USDA-ARS, Western Cotton Laboratory, Phoenix, AZ.

Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: May to August, 1995

Development and Evaluation of a New Whitefly Trap

We designed a whitefly trap based on 1) yellow color attractiveness, 2) flight response toward light, and 3) landing behavior on hosts followed by walking to undersides of leaves. Studies to evaluate the trap were superimposed on five cotton silverleaf whitefly chemical control projects conducted at USDA, ARS Irrigated Desert Research Station at Brawley, CA. Results indicate that the new whitefly trap catches reflect seasonal dispersal, population variations induced by chemical control, and seasonal population changes.

Investigator's Name(s): C.C. Chu[1], T.J. Henneberry[1], H.H. Perkins Jr.[2], D.H. Hendrix[1], and Terry Steele[1].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: March to December, 1995.

Sticky Cotton and Reduction of Lint Stickiness

Sticky cotton has been an increasing problem in some cotton growing areas of Arizona and California associated with high *Bemisia argentifolii* Bellows and Perring populations. A study was conducted in the Imperial Valley, CA in 1995 to determine the effect of Solvay Enzyme B on lint stickiness. Results showed that 2 to 10% by volume enzyme applications did not reduce lint stickiness under field conditions. Moisture of seed cotton was increased less than 1% when 50 gal/acre of water was applied daily for 7 days. On the average, seed cotton moisture varied from 3.5% in the afternoon to 5.1% early in the morning. Lint stickiness was reduced when moisture was increased to 10% and seed cotton samples were incubated at 96°F for 72 hours. The reduction was significant for thermodetector ratings of 42 to 34 for untreated cotton compared to a thermodetector rating of 27 following 10% enzyme application.

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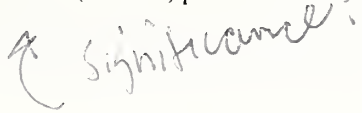
Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Alkaline Proteinases (Serine Proteinases) are not Present in Silverleaf or Sweetpotato Whiteflies

We tested both silverleaf and sweetpotato whiteflies (*Bemisia argentifolii* and *B. tabaci*) for proteinase activity and found none. Using 3-5 g of fresh whitefly adults in the case of *B. argentifolii* and 0.5 mg of *B. tabaci*, we made extracts that we concentrated and tested against casein gel, azocasein and azoalbumin at pH 7.4 and 25°C. All tests with *Bemisia* were negative, while for positive standards, we used an extract equivalent to 0.1 *Lygus hesperus* salivary gland, and we obtained clear-cut proteinase activity from all three methods with the *Lygus* extract. We further tested the whitefly and *Lygus* extracts using benzoyl-arginine-p-nitroanilide (BApNA) as a substrate for trypsin-like activity. We had strong positive readings from the *Lygus* extracts and no positives from the whiteflies. We doubled the incubation time on the casein agar plates to increase the sensitivity, and we incubated at 37°C to further enhance possible reaction, and again we had negative results with the whitefly extracts and we had very strong positive results with the *Lygus* extracts. These results led us to the conclusion that neither *B. argentifolii* nor *B. tabaci* has a serine (alkaline) proteinase.



Investigator's Name(s): Allen Carson Cohen[1], Chang-Chi Chu[1], Thomas J. Henneberry[1], Thomas Freeman[2], and Dennis Nelson[2].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Cotton Leaf Surface Features Serve as Behavioral Cues to Silverleaf Whiteflies

We examined cotton leaves looking for correlations between surface structures and vascular bundles, using standard light, confocal and electron microscopy. Using placement of eggs, nymphal positions and crawler (1st instar nymph) behavior, we evaluated the responses of whitefly nymphs to the surface features. We found that all aerial trichomes (simple and complex) originated from epidermal cells immediately abaxial or adaxial to vascular bundles, including a hairy cotton isoline DPL 115 containing 48 (+/- 2.5) trichomes/ cm^2. Leaf surface microstructures such as elongated epidermal cells were always evident wherever vascular bundles were present, including even the most minute bundles (single-stranded). Of 2000 aerial trichomes (non-glandular) that were examined, 100% originated from vascular bundle-associated epidermal cells. Eggs were generally deposited on the elongated epidermal cells associated with bundles or on cells within about 30 microns of those bundle-associated epidermal cells. Crawlers walked about 2300 microns per minute until they settled upon feeding sites that were immediately under the vascular bundles, never more than about 60 microns from the center of the abaxial bundle-associated epidermal cells. Crawlers spent at least 80% of their time in contact with bundle-associated epidermal cells, making contact with these cells either with legs or antennae.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Development of Artificial Diet for Whitefly Predators: *Serangium parcesetosum*

An artificial diet developed for *Serangium parcesetosum* (Coleoptera: Coccinelidae) is suitable for development of adults from second instar larvae. Adults that developed on this diet produced eggs and survived for at least 120 days. Eggs from these adults were fertile, and the larvae that hatched from them were able to revert to feeding on natural prey (whitefly nymphs) and adventitious prey, including pink bollworm eggs and *Sitotroga* eggs. First instar *S. parcesetosum* were unable to feed through the Parafilm membrane because their mouthparts are too small to penetrate even stretched film.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Geometric Relationships Between Whitefly Feeding Behavior and Vascular Bundle Arrangements

This study revealed strong evidence that nymphs of the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, are obligate feeders on vascular bundles and that there are large differences between different host plants as to the availability of vascular bundles to silverleaf whitefly nymphs. The relationship between nymphs and leaf vascular bundles was studied using 1) leaf sectioning and 2) techniques of leaf clearing of intact leaves. A geometric model is presented of the feeding relationship of vascular bundle-using homopterans. The relative abundance of vascular bundles was examined in six species of host plants that varied from highly preferred to tolerably acceptable. Included in order of acceptance were cantaloupe, cotton, hibiscus, broccoli, lantana and lettuce. The length of vascular bundle per 1.0 mm^2 of leaf surface ranged from about 10 mm in cantaloupe to 2.8 mm in lettuce. Salivary sheaths were found to connect with vascular bundles in 100% of the intact nymphs examined by the staining and clearing technique. However only 64% of those examined by the sectioning technique appeared to be connected to vascular bundles. About 50% of epidermal stylet penetrations were through epidermal cells; the remaining 50% went through intercellular junctions. On cotton leaves, the distance between the point of labial contact with the leaf surface and the nearest point of the vascular bundle rarely exceeded 60 µm. Our studies show that while 50% of lettuce leaf-surface was beyond 60 µm of a vascular bundle, only 10% of cantaloupe leaf surface area was outside of the 60 µm range. In cotton, mean distance from labium to the nearest point of the vascular bundle was 40.9 µm (SEM= 2.66, N= 50, range 0-80 µm). Over 98% of all salivary sheaths went to minor veins (78% to single-filament vascular bundles, nearly 20% to double filament bundles). Fewer than 2% went to bundles with 3 or more filaments.

Investigator's Name(s): Allen Carson Cohen[1], Chang-Chi Chu[1], Thomas J. Henneberry[1], Thomas Freeman[2], and Dennis Margosan[3].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Microstructure of Feeding in Nymphal *Bemisia argentifolii* in Cotton and Cantaloupe

Studies using confocal and bright field light microscopy revealed that feeding structures of 145 attached *B. argentifolii* nymphs (2nd-4th instar) always reached vascular tissue in cotton and cantaloupe leaves. Analysis of stained and cleared leaves permitted detailed examination of the course of intact feeding structures (salivary sheaths) from the plant's abaxial surface to the target tissue. Nearly every salivary sheath made complex turns and contained several branches that could be considered mistakes in the course of locating target vascular bundles. Only minor vascular bundles were found to be the targets of the whitefly nymphs. The position of minor vascular bundles were invariably associated with elongated surface cells. Although they were in contact with or close to elongated epidermal cells, all attached nymphs made mistakes in their progress towards the target bundles. Confocal microscopy revealed that the specific targets within the vascular bundles were apparently always phloem cells. This technique also showed that the sheaths often wrapped around spongy parenchyma cells on their course to vascular bundles. Once within the bundle, the sheaths often wrapped around the xylem elements and seemed always to terminate in phloem elements. Very often a single sheath that reached a minor vein would branch at the bundle into at least two and as many as six salivary sheaths.

Investigator's Name(s): Allen Carson Cohen[1], Thomas Freeman[2], T.J. Henneberry[1], Dennis Nelson[2], James Buckner[2] and C.C. Chu[1].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Microstructure of Whitefly Feeding: Scanning Electron Microscopy of Salivary Sheaths

Using freeze fracture and scanning electron microscopy, we examined several hundred leaf sections to determine the course of salivary sheaths within cotton plant leaves (both from the greenhouse and the field). We found that the sheaths had a beaded appearance with a diameter of about 2.0 µm. Some sheaths reached lengths of about 140 µm, and the few that we traced to the point of insertion of stylets appeared to terminate in phloem elements. The sheaths were extremely sinuous and complicated, many of them forming 4-6 branches. We rarely found sheaths to penetrate the mesophyll cells, but rather, they wound around and between mesophyll cells. We found numerous connections of the sheath material to cell walls. We discovered spheroid structures that appeared to be part of the salivary sheath. We suspect that the spheroid structures are "failed" efforts at producing an intact, functional sheath. The most common place to find spheroids was in epidermal cells of highly infested cotton plants. Nearly all penetrations of the salivary sheaths were through rather than between epidermal cells. At least 85-90% of the length of salivary sheaths was through air space between cells. Almost none was between cells or in mesophyll cells.

Investigator's Name(s): Allen Carson Cohen[1], Dennis Nelson[2], James Buckner[2] and Donald Brummett[1].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Nutrient Rewards for Predators of Whiteflies: Generalists' Requirements

The generalist predators, *Geocoris punctipes* and *Chrysoperla carnea* were analyzed for their abilities to use whitefly nymphs as a sole food source. Biomass, protein content and methionine content were used as separate criteria. Handling time and nutritional content were used to predict the efficacy of whiteflies as diets. Even with the assumption of 100% transfer of material from prey to predator, it is evident that these generalist predators are not suited to using whiteflies as a sustaining prey. Predictions based on transfer of biomass indicated that with 3-5 hours of feeding per day, the predators could achieve their normal adult size within their normal development period. However, considering the protein transfer, the predators would have to feed on whitefly nymphs for at least 15-17 hours per day to accumulate the normal protein content. Even more prohibitive, the predators would have to feed for over 24 hours per day to achieve normal methionine accumulation; or since this is impossible, they would have to feed for several days beyond their normal development period achievable with lepidopteran eggs or aphids. Such an extended development period is an indication that whitefly nymphs are a nutritionally unsuitable food for long-term, exclusive exploitation by either *G. punctipes* or *C. Carnea.*

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1995 to November 1995.

Effects of antibacterial materials on silverleaf whitefly oviposition, growth, survival, sex ratio and honeydew content

A variety of antibiotics, with different ranges of activity and modes of action, were used to treat the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae). The effects of these materials on oviposition, growth, survival, development to adulthood, sex ratio, and honeydew production were investigated. The materials tested were oxytetracycline hydrochloride (OTC), rifampicin, penicillin, ampicillin, lysozyme and chloramphenicol.

Offspring of adults treated with rifampicin or OTC were significantly smaller than controls. Individuals treated with OTC produced significantly less honeydew than untreated individuals. Development to adulthood was significantly lower in OTC and rifampicin treated groups. Treatments with antibacterial materials had no significant effect on oviposition rates of adults or the sex ratio of their offspring.

Each material showed similar effects whether adults or nymphs were fed through parafilm membranes or by excised leaf treatments. Of the materials tested, those that had significant negative effects on growth and development of whiteflies (tetracycline and rifampicin) interfere with bacterial protein synthesis. Those materials that primarily attack the bacterial cell walls or cell membranes (penicillin, ampicillin and lysozyme) did not have any significant effect on growth and development. Delays in development, and reduction in the percentage of offspring emerging as adults provide ample evidence that antibacterial materials have potential role in management strategies against both adult and immature whitefly stages.

Investigator's Name(s): Heather. S. Costa[1], Nick C. Toscano[1], Thomas J. Henneberry[2].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1995 to November 1995

Mycetocyte Inclusion in the Oocytes of Silverleaf Whitefly, *Bemisia argentifolii* (Homoptera: Aleyrodidae)

Endosymbiotic bacteria in whiteflies are contained in specialized cells called mycetocytes. Mycetocyte cells in whiteflies are grouped into paired structures called mycetomes located in the abdomen of both immature and adult stages.

The process of transfer of endosymbiotic organisms from the female into the developing ova of *Bemisia argentifolii* was investigated. In dissected females, individual mycetocyte cells containing microorganisms were scattered singly among developing oocytes. Oocytes with mycetocytes included were first observed in females 16 h after emergence; none were observed in individuals less than 2 hours old. The total number of oocytes greater than 0.1 mm per female increased through the fourth day then leveled off. The number of oocytes with mycetocytes included followed a similar pattern.

Stages of mycetocyte inclusion followed a pattern based on size of the oocyte. Oocytes became associated with a single mycetocyte cell when they were a mean length of 0.135 ± 0.003 mm (min. of 0.11 mm). Mycetocytes were observed inside a common membrane with oocytes, at what becomes the pedicel end of the ova, when oocytes were an average of 0.147 ± 0.004 mm long. In the final stages of ovum development, the plasma of the oocyte completely surrounded the mycetocyte and the chorion was thickened.

Mycetocytes included in oocytes had a mean length of 33 ± 0.4 µ and width of 27 ± 0.5 µ. Although the females that were dissected had opportunity to oviposit, some retained several fully developed ova. Because inclusion of mycetocytes into oocytes is a continuous process, manipulations of endosymbionts before inclusion into the oocytes should be possible at any time during adult life; however, earlier treatment of an individual would likely affect a greater proportion of their offspring.

Investigator's Name(s): Elizabeth W. Davidson[1], Rufino Patron[1], Alain Vey[2], Roger Frutos[3], Raymond St. Leger4, Lawrence A. Lacey[5], and Donald L. Hendrix[6].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1995 - January 1996.

Effects of Destruxins from *Metarhizium anisopliae* and *Bacillus thuringiensis* Delta-Endotoxins on Adult Silverleaf Whitefly, *Bemisia argentifolii*

A novel bioassay system has been devised for the silverleaf whitefly, *Bemisia argentifolii*. Adult whiteflies are gently aspirated directly into a bioassay vial, where they feed on sucrose solutions containing potential intoxicants. Mortality and honeydew are scored at 24 and 48 h.

Destruxins A, B and E were extracted from culture filtrates of *M. anisopliae* strain Ma23 using methylene chloride, and subjected to chromatography on a silica column. The fraction which eluted with acetone was evaporated to a powder and found to contain about 50% destruxins. Destruxins from *M. anisopliae* strain ARSEF23 were semipurified on 1:1 Dowex 50 and Dowex 1. The resulting dried powders were disolved in 95% ethanol and diluted at least 100-fold in 27% sucrose containing yellow food dye for assay.

After 48 h, destrusinx from strain Ma23 at 3 µg/ml produced ca. 80% *Bemisia* mortality and significantly reduced honeydew production. At 100 µg/ml destruxins from ARSEF23 produced 80% mortality and reduced honeydew production.

Destruxin E has been reported to kill and repel aphids when applied as a spray to leaves or through the plant vascular system (P. Robert and G. Riba. 1989. *Mycopathologia* 108:179-183). However, the activity of destruxins to whiteflies has not previously been reported. In our bioassay system, the activity of destruxins from Ma23 was equal to that of the insecticides Imidocloprid and Ivermectin. Our results suggest that destruxins are potentially useful agents against this whitefly, which is a world-wide pest in the subtropics.

The following *B. thuringiensis* delta-endotoxins were fed to whiteflies at the indicated concentrations without producing any significant mortality or change in honeydew production: CryIB (88 µg/ml); CryIC (59 µg/ml); CryIE (152 µg/ml); CryIA(a) (96 µg/ml0; CryIA(b) (6.9 µg/ml); CryIA(c) (51 µg/ml); CytA (100 µg/ml); HNC (76 µg/ml); HNE (91 µg/ml);(all activated) and CryIA(c) 925 µg/ml) and CryIA(a) (140 µg/ml) (solubilized only).

Investigator's Name(s): Elizabeth W. Davidson[1], James K. Jancovich[1], Mark Lavine[2], and Donald L. Hendrix[2].

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1995 - January 1996.

Feeding and Behavior of *Bemisia argentifolii* Larvae Using an Artificial Feeding System

The silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, is a major pest of cotton and other crops in the southern United States and elsewhere in the subtropics. Agents which must be ingested are difficult to assay against this insect because it feeds exclusively on plant phloem sap. To our knowledge neither *B. argentifolii* or any other whitefly has been successfully cultured on an artificial diet. We have designed an artificial feeding system that allows development of this insect from egg to adult, under sterile conditions. This system consists of a semi-synthetic diet and a fluid-filled chamber machined from polycarbonate plastic with a stretched Parafilm® membrane, from which we have studied larval development, feeding behavior and the anatomy and function of the digestive tract and filter chamber within the larval stages. The later experiments involve use of video cameras and fluorescent tracers. Although the morphology of the digestive tract and filter chamber in the adult whitefly has been previously described by light and electron microscopy, the in vivo functioning of this complex structure has not been previously recorded in action.

This system should prove very useful in studies of the physiology of the whitefly larvae. It should also provide a mechanism for the assay of potential intoxicants for this insect which may be expressed in the plant phloem. In addition, due to the length of time involved in the culture of insects on this system, it is proposed as a mechanism of studying intoxicants which exert their effect over a long period of time.

Eggs, isolated from plant leaves, were treated with soapy water, 70% ethanol and 10% household bleach. After surface sterilization and washing, they were placed on the Parafilm surface to hatch (2-3 days), and then held at 25-27°C and 30-45% humidity. Larvae were observed daily via a dissecting microscope.

Typically, 2-10% of the eggs in the chamber hatched. Hatching seemed to depend upon the age of the eggs at harvest, handling times and humidity. Approximately 50% of the first-instar larvae ('crawlers') attached to the Parafilm and began feeding. Most larval mortality occurred at this stage. Molting to second and more advanced instars was only observed on a complex diet. Dietary components were found to be a critical function of the development past the third instar stage.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: November 1, 1994 - October 31, 1995.

Occurrence of Tomato Infectious Chlorosis in Europe

A new virus of tomato and other crop and weed hosts was found in California in 1993. Tomato plants affected by the virus exhibited interveinal yellowing, necrosis and severe yield losses. The virus was described as tomato infectious chlorosis virus (TICV), and is transmitted in a semi-persistent manner by the greenhouse whitefly, *Trialeurodes vaporariorum*.

A tomato plant showing unusual malformation and leaf reddening, stunting, and poor fruit set was observed in a glasshouse at Albenga, Liguria, north western Italy. The plant was shown to be infected with a clostero-like virus transmitted by *T. vaporariorum*.

The Italian virus isolate was transmitted to tomato and a few other members of the Solanaceae. The virus particle size, insect transmission and lack of a serological response to beet pseudo yellows virus (BPYV) and lettuce infectious yellows virus (LIYV) was similar to the TICV from California.

ELISA tests demonstrated that antiserum against TICV reacted with tomato tissue infected with TICV from California and the Italian isolate, but not with tissue from healthy plants. Complementary DNA corresponding to the virion RNA isolated from TICV-infected tissue was cloned. Digoxigenin-labeled riboprobes reacted specifically with RNA extracted from TICV-infected plants and from plants infected with the Italian isolate in dot blot analyses. No hybridization reactions were observed with other whitefly-transmitted closteroviruses including BPYV, LIYV, lettuce chlorosis, or cucurbit yellow stunting disorder.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: September 1, 1994 - August 31, 1995.

Morphological bases for whitefly transmission of viruses

Bemisia's salivary system consists of paired primary and accessory glands in the prothorax, to either side of the thoracico-abdominal ganglion. Ducts from each pair fuse to form lateral ducts that travel anteroventrally to the midline where their duct cells fuse to form a dual-channeled medial duct that traverses the hypoharynx to join the short, single-channeled afferent duct. The latter empties posteromedially into the rim of the salivary pump's cupula. Saliva exiting the pump, via an efferent duct, enters the salivary canal of the maxillae where food from the maxillary food canal enters the precibarium. The salivary pump can be likened to a hypodermic syringe in both form and function. The pump's cupula is analogous to the wide body of the hypodermic syringe; its piston is analogous to the hypodermic's plunger, and the efferent duct and contiguous maxillary salivary canal are analogous to the narrow stem of the hypodermic syringe and its attached needle, respectively. Negative or positive pressures are created by retracting or lowering the piston, respectively. Retracting the piston by contracting the piston retractor muscles creates a vacuum that sucks saliva from the open (cupula muscles relaxed) afferent duct into the cupula. Subsequent contraction of the cupula muscles (afferent duct closed) and simultaneous relaxation of the piston muscles creates positive pressure to eject saliva from the cupula through the efferent duct into the salivary canal of the maxillae. Circulative geminiviruses apparently are inoculated to plants when whiteflies excrete virus-laden watery saliva into the phloem during "declogging" activity aimed at clearing the lumina of the feeding apparatus.

The basal part of the feeding apparatus is comprised of six exoskeletal lobes from the venter of the head capsule: clypeolabrum anteriorly, paired lora anterolaterally, paired maxillary plates posterolaterally, and hypopharynx posteriorly. Another lobe, the labium, emerges from the median of the cervical venter. The cibarium, formed by the apposition of the epicibarium and hypocibarium, is divided by a cibarial valve into antecibarium and postcibarium. The latter functions as the cibarial or "sucking" pump. The cibarium's wholly noncellular, cuticular walls and the origin of its valve and pump retractor muscles from the anteclypeus and postclypeus, respectively, attest its evolutional linkage to the preoral cibarium of the more primitive orthopteroid feeding apparatus. The true mouth or opening between the cibarium and the intima-lined, cellular pharynx coincides with the frontoclypeal suture and the distal-most descent of the frontal ganglion.

Similarities among the morphologies of whitefly, aphid and leafhopper feeding apparatuses further confirm the ingestion-egestion hypothesis: homopteran vectors acquire noncirculative viruses by ingestion, carry them externally on the stylets or "internally" on the cuticula-lined lumina (hence, "cuticula-borne") of the feeding apparatus, and inoculate them to plants by egestion. However, others have analysed very similar morphological findings and concluded that homopteran vectors cannot egest and that they inoculate noncirculative viruses by "extravasation." But extravasation, a highly specialized term in medical pathology, refers to leakage of fluids, particularly blood, from vessels into surrounding intercellular spaces. It also misleadingly links noncirculative virus transmission to an unpredictable, abnormal, passive, vector activity. We propose the exact opposite: noncirculative transmission is linked to the predictable, normal, active, functional, vector activities of ingestion and egestion, and the homopteran feeding apparatus is equally equipped for both. Obviously, aphids, leafhoppers and, by morphological similarity, whiteflies too can and do actively ingest and egest . And the fact that they can do so uninterruptedly indicates that they can create and sustain either negative or positive pressure in the pump chamber for prolonged periods during which the chamber fills (ingestion) or empties (either egestion or "swallowing"), respectively. The idea of virus inoculation by "extravasation" resulted from the mistaken notion that the cibarial pump can only be opened or closed at its anterior end. However, an analysis of the pump's morphology indicates that it functions like a reversible bellows. Contraction of the anterior pump retractors with the cibarial valve open (valve retractor muscles contracted) and posterior pump retractors relaxed (pump closed posteriorly) results in negative pump pressure and, hence, ingestion. Conversely, a wavelike posteroanterior relaxation of the pump retractors with the valve open results in egestion. And a wavelike anteroposterior relaxation of the pump retractors with the cibarial valve closed results in food being "swallowed" past the true mouth into the pharynx of the foregut.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: September 1, 1994 - August 31, 1995.

Preparation of whole insects for combined light and electron microscopy and immunocytochemistry

The following protocol is presented as a less expensive (equipment-wise) alternative to UV-cold polymerization of LR White. In our laboratory, the protocol has yielded high-quality embeddings of whole insects, the sweet potato whitefly *Bemisia tabaci* Gennadius, with excellent trimming and sectioning characteristics for both light and electron microscopy. Additionally, polymerization at a more moderate temperature (55°C) preserves antigenicity for immunocytochemistry. The latter was an important consideration since we wanted to study the fate of whitefly-borne plant viruses both in the vector and plant hosts.

The chamber for replacing air with dry, nitrogen gas (N_2) is built using 3/8 in-thick plexiglass panels. However, other air tight containers such as a modified preserve jar ought to work well too (Harris et al., 1995, *Microsc. Res. Tech.* 33:264-265). A tank of dry N_2 gas, fitted with pressure and flow rate valves, was connected to the chamber inlet line with polyethylene tubing. Polyethylene tubing from the exit line was inserted into a 2-liter flask half-full with water for both visual and audible (bubbling) monitoring of the gas flow through the tank. With both chamber valves fully open, a flow rate of 10 ft^3/h was chosen as one that replaced the air in the chamber at a reasonably fast rate while creating minimal turbulence in the chamber. At this rate of flow, the chamber-volume replacement rate (CVRR) is greater than two chamber vol/min. Therefore, assuming perfect mixing of the gases, greater than two thirds of the existing gas in the chamber would be displaced each min, thus reducing the air in the chamber by more than one third each min. The approximate fractions of the gas in the chamber that are air and dry N_2 after any 10 min are $(1/3)^{10}$ air + $[1-(1/3)^{10}]$ N_2 or 0.0000169 air + 0.9999831 dry N_2. Even using a conservative CVRR of 1 chamber vol/min, the percent N_2 by volume in the chamber after 10 min, $[1-(1/2)^{10}]$ X 100, would still be >99.99%. By applying Boyle's Law, it was determined that the nitrogen in the closed chamber would be raised to ca. 1.6 psi above atmospheric pressure at the polymerization temperature of 55°C. Our chamber tested leakless up to 5 psi.

Whiteflies are fixed in 3% paraformaldehyde and 0.5% glutaraldehyde in 0.1 M Sörensen's buffer, pH 7.2, for 1-2 h, given two 15-min rinses in the same buffer, dehydrated in ethanol (15 min in 50% followed by 15 min in 70%), infiltrated for 1 h on a rotary mixer (Ted Pella, Inc.) with a 2:1 dilution of LR White (medium grade, EMS) and 70% ethanol followed by three changes in 100% LR White for 1 h, overnight, and 8 h, respectively. The insects are then transferred to flat, polyethylene, EFFA embedding molds (Ernest F. Fullam, Inc.) filled with "nitrogen-infused" 100% LR White. The molds are topped off, covered with Aclar® embedding film (Ted Pella, Inc.), and placed in the polymerization chamber which is then sealed and flushed with N_2 for 10 min at a flow rate of 10 cfh. Blocks are trimmed and sectioned with glass or diamond knives on a Porter-Blum MT2-B ultramicrotome. For light microscopy, sections are transferred to droplets of filtered water on glass slides coated with 0.01% poly-L-lysine (Sigma), dried at 40°C, stained with methylene blue and basic fuchsin, and viewed and photographed under a Zeiss Standard 25 compound microscope. Light microscopy also enabled us to study *Bemisia's* internal morphology and to choose areas of specimens for ultrathin sectioning and immunocytochemistry. Antigenicity is preserved by lowering the polymerization temperature to 55°C. Virus particles have been localized both in the vector and virus-infected plants using immunogold-silver staining followed by light and electron microscopy.

While establishing the present protocol, many abbreviated versions were tested. That testing led us to conclude that each and every step of the protocol ("infusing" the liquid resin with N_2, evacuating or degassing the N_2-infused resin, covering the mold with Aclar®, and polymerizing the resin in a nitrogen atmosphere) is essential to consistently obtaining high-quality embeddings at a polymerization temperature of 55°C. We have processed whole-insect specimens on more than a dozen occasions since adopting this oxygen-free polymerization protocol. To date, all blocks obtained have had excellent trimming and sectioning characteristics. Serial sectioning of whole insects is now not only possible but routine.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1995 - January 1996.

Isolation and Characterization of the Large Oligosaccharides in *Bemisia* Honeydew

Honeydew contamination is the leading cause of problems in processing cotton in textile mills around the world. *Bemisia* honeydew is a complex mixture consisting of at least twenty different oligosaccharides. Cotton fiber stickiness due to honeydew contamination is a function of the type of sugars in the honeydew. For example, the major sugar in *Bemisia* honeydew, trehalulose, is much more sticky than glucose. A significant percentage of the sugars in *Bemisia* honeydew are unknown saccharides larger than trisaccharides. Some of the objectives of our current research are to identify these larger sugars, determine their biochemical synthesis within the whitefly and determine their contribution to the stickiness of *Bemisia* honeydew-contaminated cotton fiber.

Honeydew excreted from *Bemisia argentifolii* was isolated from a bale of cotton which wad been harvested from field infested with this insect. To remove the honeydew sugars the fiber was washed, 1 kg at a time, in a household washing machine. The eluted sugars were removed from the aqueous solution by binding them to a mixture of Celite and charcoal. They were then removed from the charcoal by washing with 95% ethanol. After removal of the ethanol and water from the honeydew, it was chromatographed on a large (12.5 X 90 cm) column of Celite and charcoal. Sugars were eluted from this column with an increasing concentration of *n*-propanol. Oligosaccharides which eluted from the charcoal-Celite column with 6% propanol were then chromatographed on a large (5 X 120 cm) BioGel P-2 column which separated the sugars by size. This produced three fractions of sugars larger than trisaccharides, including two sugars which appear to be either penta- or hexasaccharides.

One of the saccharides we isolated in this fashion from honeydew was shown by MS and NMR to be a unique tetrasaccharide. This sugar was found to have the following structure: α-D-Glucose-(1→4)-α-D-Glucose-(1↔1)-α-D-Glucose-(4←1)-α-D-Glucose. Several other oligosaccharides which were also isolated from the BioGel column have been synthesized from sucrose by a protein fraction from homogenized adult whiteflies. From their HPLC elution, these oligosaccharides appear to be either tetra- or pentasaccharides. When asymmetrically-labeled sucrose was used as a substrate (i.e., [^{14}C-fructosyl]-glucose), these saccharides incorporated the ^{14}C label. The labeled fructose moiety did not appear to be converted to another sugar, thus it is concluded that these oligosaccharides contain fructose.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January, 1994 to December, 1995.

Comparative Mating Behavior of Three Whitefly Species

The mating behaviors of three species of whiteflies were determined by use of time lapse video recorder with camera mounted on binocular microscope at 16 x magnification. The adults were confined to a cotton leaf with a 5 mm diameter clip cage. The species observed were: silverleaf whitefly *Bemisia argentifolii* Bellows and Perring, Bandedwinged whitefly *Trialeurodes abutilonea* (Haldeman), and greenhouse whitefly *Trialeurodes vaporariorum* (Westwood). A frame grabber was used to print selected frames to illustrate differences in behavior.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1-December 31, 1995

Bemisia is known to cause a number of plant disorders as a result of feeding. Our laboratory has been conducting research on plant disorders resulting from *Bemisia* feeding and has previously reported on two pathogenesis-related (PR) proteins (M_r 31,000 and 70,000) of unknown function that appeared in the intercellular fluid of pumpkin plants fed upon by whiteflies. We extended these studies to tomato (*Lycopersicon esculentum* Mill.) and found that several PR proteins are induced by *B. argentifolii* feeding. Tomato plants were placed in cages and exposed to whitefly adults for 2 weeks. Leaf samples were taken from infested and uninfested plants and subjected to electrophoretic and enzyme analyses. Plants fed on by *Bemisia* had elevated levels of chitinases (ca. 6-fold), peroxidases (ca. 4-fold), β-1,3-glucanases (6-fold) and chitosanases (1.3-fold) over those found in uninfested plants when based on specific activity. Immunodetection via western blotting corroborated the enzyme data. The immunoblots showed that chitinase, β-1,3-glucanase, P2 and P4 were induced in infested plants. Induction of these PR proteins is rapid occurring within 24 h of exposure to whitefly adults. Leaf protein levels were significantly lowered in plants exposed to whiteflies.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1993-January 1995.

Phenotypic Plasticity in Whiteflies: An Interpretation

Variation in the number of setae on pupae of *Bemisia tabaci* and wax extrusions on *Trialeurodes vaporariorum* is well recognized. Russell (1948) pointed out difference in the pupal morphology of *T. vaporariorum* on smooth and hairy hosts and synonomized 9 species of *B. tabaci* (1957) that had been misidentified due to pupal variation. Explanations for the variation of setae have been reported by Azab et a. 1969, Chang 1969, David & Ananthakrishnan 1976, Guershon and Gerling 1994, Harakly 1973, Monanty and Basu 1986, and Mound 1963, 1965. These previous studies were based on the degree of pubescence of the host plant or seasonal factors on pupal variation.

We reared both *B. tabaci* and *T. vaporariorum* on a variety of host plants and confirmed the previous reports of the presence and degree of pupal structures relative to density dependence of leaf surface trichomes. We examined several plant species and used the zinnia to demonstrate density dependence. Also it was determined by using this host that the presence of pupal structures is entirely based on the short term crawler "experience" or stimulation from its environment which appears to be independent of host morphology. Therefore, we further established cohorts of both whitefly species in relatively high or low densities on glabrous (smooth) lettuce leaves and obtained a significantly higher percentage of pupae with either setae or wax extrusions in the high density cohort than low density cohort. *T. vaporariorum* was determined to have a lower threshold of stimulatory response than *B. tabaci*. Thus, on smooth leaf surfaces the higher the density of whiteflies, the greater the number of pupal exuviae with either setae or wax extrusions.

Since both *B. tabaci* and *T. vaporariorum* are highly polyphagous and the pupal morphology is variable, we examined the relationship of a stenophagous species to its host. Also in the subfamily Aleyrodinae, the azalea whitefly *Pealius azaleae*, (Baker & Moles) represents a paradigm for a stenophagous species of whitefly. *P. azaleae* is reported to develop only on *Rhododendron mucronatum* and it's derivatives, one of the most hirsuit (hairy) species. The morphology of the abaxial leaf of *R. mucronatum* includes a dense mix of glandular and nonglandular trichomes yet, the dorsum of the pupal exuviae of *P. azalea* has only two pairs of minute setae that are apparently stable and visible only with a compound microscope. Thus the obvious question, why the labile condition in polyphagous species and the absence in one that apparently is stenophagous. It is suggested here that this unusual phenomenon of phenotypic plasticity in the morphology of the pupal exuviae of the polyphagous *Bemisia* and *Trialeurodes* species is neither Müllerian nor Batesian mimicry, but an individually adaptive response based on the experience of the crawler to host leaf surface morphology prior to settling or, more importantly, stimulation to the crawler, i.e. crowding, insect debris such as eggs, and surface texture, independent of host trichomes. The selective adaption of this density-induced polyphenism form of mimicry results in the polyphagous whitefly pupae generally blending with the morphology of each host species probably as a form of protection against enemies. Thus, the question: how is a polyphagous polyphenic species to be defined?

Russell, L. M. 1948. USDA, Misc. Pub. No. 635.; Russell, L. M. 1957. Bull. Brooklyn Entomol. Soc. 52: 122-123. (Other citations available upon request)

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: September 1, 1994 - August 31, 1995.

Sweet potato whitefly-squash leaf curl virus immunocytochemistry

Colonies of *B. tabaci* were maintained in a climate-controlled insectary in cages in growth cabinets under 16 h of daylight, 60% relative humidity, and day and night temperatures of 29° and 26°C, respectively. Viruliferous whiteflies were maintained on squash seedlings infected with SLCV, whereas virus-free cultures were reared on sweet potatoes (*Ipomoea batatas* L.).

Specimen preparation at room temperature. SLCV-infected squash leaves and adult female and male whiteflies were processed as previously described (Harris *et al.*, 1995, *Microsc. Res. Tech.* 33:264-265). In order to enhance fixative penetration, whole insects were submerged in 0.1 M Sörensen's buffer, pH 7.2, and legs and wings were removed with fine forceps under the stereomicroscope. Whiteflies were fixed in 3% paraformaldehyde and 0.5% glutaraldehyde in Sörensen's buffer for 1.5-2 h on a rotary mixer. After two 15-min rinses in Sörensen's buffer, insects were dehydrated in a graded ethanol series, 15 min in 50% followed by 15 min in 70% ethanol, infiltrated for 1 hr on a rotary mixer with a 2:1 dilution of LR White and 70% ethanol, followed by three changes in complete LR White for 1 h, overnight and 8 h, respectively. The insects were then transferred to flat polyethylene embedding molds, filled with nitrogen-infused complete LR White and polymerized in a nitrogen polymerization chamber for 48 h at 55°C. Blocks were sectioned with glass or diamond knives on a Porter-Blum MT2-B ultramicrotome.

Immunocytochemistry. semithin sections, about 1 µm thick, were mounted in a drop of water on glass slides coated with 0.01% poly-L-lysine, dried at 40°C, stained with the silver, poststained with methylene blue and basic fuchsin, and viewed and photographed under a Zeiss Standard 25 compound microscope. For TEM, ultrathin sections (60-90 nm) were collected onto formvar-coated nickel grids and floated face down (15 min) on drops of 0.02 M glycine in Tris-buffered saline, transferred for 20 min to blocking buffer, incubationed in SLCV antiserum, rinsed in blocking buffer, transferred to immunoglobulin-gold complex, rinsed first in blocking buffer then water and stained with uranyl acetate and lead citrate. Virus-exposed whiteflies used as controls in this study were subjected to nonimmune rabbit serum or blocking buffer or antiserum to lettuce infectious yellows virus, as the substitute for the primary antibody, prior to immunogold labeling. Virus-free whiteflies were first exposed to SLCV antibodies followed by immunogold labeling. SLCV was localized by IGSS-LM and IGL-TEM in the following systems and organs of viruliferous whiteflies: digestive system (esophagus, filter chamber, midgut and hindgut), excretory system (malpighian tubules), hemocoel, mycetome (mycetocytes), fat body (fat cells), reproductive system (follicular cells and oöcytes) and salivary system (primary and accessory glands and their duct systems). Gold label was not present in virus-exposed controls or immunotreated virus-free controls.

Virus invades numerous organs and tissues in its passage from the maxillary food canal in the feeding apparatus (acquisition) to the ducts of the salivary gland system (inoculation). In the digestive system virions are capable of penetrating the intima and epithelium of the foregut to directly enter the hemocoel in close proximity to the salivary glands. The latter might explain the short latent periods observed for geminivirus transmission. After penetrating the basal laminae of the salivary glands, virions move into cisternae formed by infolding of the basal plasmalemma. Specific attachment of virus particles to the surface of this dynamic, membrane system enables virions to be carried by membrane flow to microvillous canaliculi formed by the infolded apical plasmalemma and, by exocytosis, into the salivary duct lumen. The presence of gold label and virus particles around and in nuclei of affected cells of several organs (follicular cells, oöcytes, mycetocytes, and epithelial cells) and gross as well as ultrastructural abnormalities of affected organ systems (reproductive, digestive and excretory systems) suggest that SLCV may multiply in one or more tissues of its vector.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January 1, 1995 - December 31, 1995.

Detection of Geminivirus in Whitefly Extracts, Saliva, and Honeydew by Polymerase Chain Reaction (PCR)

Members of the *Bemisia tabaci* (Genn.) species complex are the exclusive vectors of whitefly-transmitted (WFT), or Subgroup III geminiviruses, worldwide. The mode of virus transmission is persistent and highly vector-specific, yet, the transmission pathway and the mechanisms underlying the cellular and molecular basis of geminivirus-vector specificity remain ill-defined. We hypothesize that although both vector and non-vector adult whiteflies ingest soluble food and geminivirus virions/DNA from the pholem sap of geminivirus-infected plants, geminivirus virions (the putative transmissible form) are specifically protected while being shuttled through the gut to the hemocoel, and from the hemocoel to the accessory salivary glands/mouthparts of the whitefly vector, from where virions are delivered to the phloem by the stylet during feeding, all by as yet unknown mechanisms and pathways. In contrast, geminivirus virions are non-specifically degraded and/or shunted out of the body in the non-vector species, having not reaching the ultimate site from which they may be returned to the plant phloem during feeding.

A polymerase chain reaction (PCR) assay was used to monitor squash leaf curl geminivirus (SqLCV) in extracts of adult whiteflies, *Bemisia tabaci* (vector) and *Trialeurodes vaporariorum* (non-vector), given incrementally longer acquisition access periods (AAP) ranging from 0.5- 96 hr on SqLCV-infected or healthy pumpkin. PCR primers designed to amplify the core region of the SqLCV coat protein gene yielded an expected 550 bp product when virus was detectable in adult whiteflies or virus-infected plants, whereas, no analagous product was detected in non-viruliferous adult whiteflies or in healthy plant controls. In time-course experiments, the frequency with which SqLCV was detectable by PCR increased in both vector and non-vector whitefly species, given correspondingly longer AAP's. Interestingly, the frequency of SqLCV detection increased linearly in the non-vector, *T. vaporariorum*, while detection in the vector increased linearly between 0.5 hr-12 hr, decreased following 24-48 hr AAP's, and increased again after a 72 hr AAP. Similar observations have been reported in which virus-vector relationships are defined by whitefly-mediated virus transmission to a bioassay host.

The ability of adult whiteflies to ingest SqLCV from infected plants was monitored by PCR using an artifical feeding chamber assay. Whiteflies were allowed AAP's of 2, 8. 24 and 48 hr on healthy or SqLCV-infected plants, followed by a 24 hr (simulated) inoculation access period (IAP) on a sucrose substrate in artificial feeding chambers. The presence of SqLCV DNA was monitored by PCR in adult whiteflies, whitefly saliva plus sucrose substrate (collected from feeding chambers), and honeydew, after a 24 hr IAP. SqLCV was detected in saliva, honeydew, and extracts of *B. tabaci* , whereas, virus was detected in the the honeydew and adult extracts, but not in the saliva/sucrose substrate for *T. vaporariorum*. Here, we provide the first direct evidence for geminivirus in whitefly vector saliva, and demonstrate that at least some form(s) of viral DNA pass through adult vector and non-vector whiteflies, given a sufficient AAP, as evidenced by viral DNA in whitefly honeydew.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: January - December, 1995.

Uptake and Metabolism of Plant Proteins by the Silverleaf Whitefly

Contrary to widespread belief, plant phloem contains relatively high concentrations of amino acids and proteins in addition to sucrose. To determine if plant proteins can be taken up and metabolized by the silverleaf whitefly (*Bemisia argentifolia* Perring & Bellows), whiteflies were fed through parafilm on either sulfur-labeled leaf proteins isolated from cotton (*Gossypium hirsutum* L.) leaves or the sulfur-labeled amino acids, methionine and cysteine. After 24 h of feeding on labeled protein, label was taken up by the whiteflies and a significant portion, 16%, was excreted in the honeydew mostly in the form of free amino acids. Whiteflies feeding on the labeled amino acids took up or retained about twice as much label over the same period of time, excreting 25% in the honeydew. On both diets, a considerable portion of the label in the whiteflies was in the form of protein. After feeding on labeled protein, approximately 41% of the radiolabel in the whiteflies was in protein and 42% in free amino acids, compared to 32% in protein and 42% in free amino acids for whiteflies that fed on labeled methionine and cysteine. The polypeptide profiles of labeled whitefly proteins were similar on both diets and both profiles resembled the general profile of whitefly proteins. These results indicate that the silverleaf whitefly can take up plant proteins, degrade the proteins to free amino acids, and either excrete the amino acids in the honeydew or else use them for *de novo* protein synthesis. Uptake and metabolism of labeled amino acids and possibly proteins also occurred when whiteflies fed on cotton leaves that were supplied with sulfur-labeled amino acids through the transpiration stream. Analysis of the honeydew fraction from whiteflies feeding on radiolabeled leaves showed that most of the excreted label was in the form of free amino acid. However, a small portion of the label was incorporated into protein. Gel electrophoresis showed that the labeled protein consisted primarily of a single species with a subunit molecular mass of 22.4 kilodaltons (kD). The identity of the 22.4 kD protein is not known and was not revealed by limited protein sequencing. We are currently investigating the identity of the protein and its possible role in honeydew metabolism.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: July to August, 1995.

Efficacy and Trap Comparison in Monitoring Adult Whitefly Population Densities in Cantaloupe

A whitefly trap developed by Chu and Henneberry in 1995 was tested in a cantaloupe field at University of Arizona Maricopa Research Center, Arizona in 1995. It was compared with 3 by 5 inch yellow sticky card traps and dome traps. Results showed that the new whitefly trap effectively caught adults. Numbers caught by the trap increased as whitefly population densities increased during the season. The numbers caught were also comparable to numbers caught with a dome trap and to a lesser extent to adults counted resting on leaves. Results showed the catches were not comparable to numbers of adults caught with yellow sticky card traps. The new whitefly trap may be a useful survey and monitoring tool.

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Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: April 1994 to November 1995.

Transmission of Tomato Mottle Geminivirus by *Bemisia argentifolii*

Experiments were conducted in 1994 and 1995 at the Central Florida Research and Education Center in Leesburg and the Gulf Coast Research and Education Center in Bradenton to characterize transmission of tomato mottle geminivirus and to evaluate the effects of different experimental conditions. The ultimate objective of the work is to develop consistent, reliable standardized tests that will give similar results in different laboratories so that we can efficiently evaluate virus-resistant plants developed in a traditional breeding program as well as transgenic plants expressing different viral genes.

Transmission efficiency and inoculation access period were determined at both locations. Efficiency was lower than that obtained for some other geminiviruses, ranging from 20% to 40% for 5 whiteflies per plant and 80% to 100% for 40 whiteflies per plant. Transmission was very low for single whiteflies (up to 5%). Overall averages were similar between locations but variability between experiments at a location was high until the number of plants per treatment was increased from 10 or 15 to 20 or 30. For inoculation access experiments, all whiteflies were given a 48-hour access to infected plants. The minimum time required for transmission was 1 hour in Leesburg and 2 hours in Bradenton, although 20-24 hours was required for high levels of transmission.

The minimum acquisition access period, determined in Leesburg, was 4 hours, when tomato was used as both a host plant for the whitefly and for the virus, and 8 hours when collards were used as a host plant for whiteflies. Even with a 24-hour acquisition access period, transmission was much higher if whiteflies were not made to switch host plants (42% versus 20%). The effect of whitefly host plant on transmission (inoculation access) was not significant, if whiteflies had previous access to an infected tomato for at least 48 hours.

At Bradenton, viruliferous whiteflies were given access to healthy plants in individual cylinder cages. At Leesburg, clip cages were used that were screened on both open ends with mesh large enough for whiteflies to feed and oviposit through. Cage types were compared at Bradenton. Differences in transmission, averaged over four experiments, were not significant, although in one experiment, the use of clip cages resulted in much lower transmission, possibly due to lack of good contact between the clip cage and leaf.

Investigator's Name(s): Gail C. Wisler, Hsing-Yeh Liu, Ruhui Li, and James E. Duffus.

Affiliation & Location: USDA-ARS, Crop Improvement and Protection Research Unit, Salinas, CA 93905

Research & Implementation Area: Section B: Fundamental Research—Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions.

Dates Covered by the Report: November 1, 1994-October 30, 1995.

Partial Characterization and Diagnosis of the Lettuce Chlorosis Virus of Lettuce

A new closterovirus of lettuce, termed lettuce chlorosis virus (LCV) was separated from the yellowing complex of viruses in the desert southwestern United States in 1991. Symptoms of LCV on lettuce are very similar to those induced by lettuce infectious yellows virus (LIYV). However, LCV is readily distinguished from LIYV by lack of reciprocal serological cross-reactions, differences in susceptible hosts, and differences in whitefly vector efficiency. An important difference in host range between LCV and LIYV is the fact that LCV does not infect members of the Cucurbitaceae, whereas cucurbits are hosts of LIYV, and contribute significantly to its epidemiology. LIYV is transmitted efficiently by the A biotype of *Bemisia tabaci*, but inefficiently by the B biotype (*B. argentifolii*). In contrast, LCV is transmitted efficiently by both vectors.

Partial molecular analysis of LCV indicates that the virion RNA is ca. 8.0 kb, and the mobility of the dsRNA corresponds to the approximate size of the ssRNA in agarose gels. The virus has been purified, and antiserum has been prepared which reacts with LCV infected tissues in indirect-ELISA and western blot analyses. The coat protein from infected tissues and purified preparations is ca. 32 kDa. Measurements from over 250 flexuous, filamentous particles in leaf dips show a normal length of 800-850 nm and a width of 12 nm. A nonradioactive molecular probe has been prepared which also reacts with LCV infected tissues in dot blots and with virion RNA in Northern blot analyses, again showing a size of ca. 8.0 kb. This probe does not react with uninfected plant tissues or with LIYV, beet pseudo yellows virus, or tomato infectious chlorosis virus infected tissues.

Preliminary cytological analyses indicate that LCV is phloem limited and produces cytoplasmic vesicles. This information, in addition to particle morphology and vector specificity suggests that LCV is a member of the Closteroviridae.

TABLE B. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved		Significance
		Yes	No	
B.1 Studies of feeding behavior: sensory receptors, ultrastructure, morphology, digestive physiology; intra- and interspecific competition.	Yr. 4: Continue research begun earlier; identify weak links for management-based research.			
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction.	Yr. 4: Continue basic studies; investigate approaches for interrupting or altering key biological processes.			
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species, genetics and genetic diversity. Develop dsRNA and cDNA probe.	Yr. 4: Finish analysis of SPW character development of rapid identification system.			
B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Yr. 4: Complete systematic analysis of *Bemisia* species; complete phylogenetic analysis of at least morphological and DNA sequence information.			
B.5 Identify and define SPW toxicogenic effects.	Yr. 4: Characterize toxicogenetic molecules and mode of action. Utilize probes for field Ids.			
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Yr. 4: Determine specific genes and gene products associated with SPW metabolism.			

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diagnostics and resistance; virus-vector specificity and interactions.	Yr. 4: Develop strategies for engineered resistance; prototype isolates based upon molecular characterization and distribution studies; biological, molecular parameters, viral designations standardized; methods for identification; mechanisms of vector transmission.			
B.8 Study epidemiological parameters: vector population dynamics; disease thresholds; identify sources of inoculum, distribution, severity, and prevalence of pathogens. Correlate efficiency of transmission with biotypes, diversity and parameters of cropping systems.	Yr. 4: Continue application of diagnostics to field epidemiology studies. Evaluate distribution, reservoirs using diagnostics; evaluate resistance in field studies.			
B.9 Study mating and oviposition behavior.	Yr. 4: Identify factors that may be manipulated to manage or present mating; examine potential of attracticides and manipulation of crop production in reducing oviposition.			
B.10 Determine factors influencing host plant selection and host acceptance.	Yr. 4: Determine interactions of semiochemicals with environmental factors, incl. natural enemies.			
B.11 Identify plant nutritional and defensive responses to SPW and their effects on SPW and natural enemies.	Yr. 4: Identify source of defensive factors in plants and their targets in SPW; continue studies of tritophic level interactions.			

SECTION C: CHEMICAL CONTROL, BIORATIONALS, AND PESTICIDE APPLICATION TECHNOLOGY

Co-Chairs: John Palumbo and Phil Stansly

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): D.H. Akey[1], J. Goodwin[2], and I.W. Kirk[3].

Affiliation & Location: [1]USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ 85040[2], Custom Farm Service of AZ, P.O. Box 338, Stanfield, AZ 85272, and [3]I. W. Kirk, Agric. Engineer, Areawide Pest Management Res. Unit, SCRL, ARS, USDA, College Station, TX.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1995.

Comparison of Day versus Night Applications for Control of Silverleaf Whitefly and Pink Bollworm

The silverleaf whitefly (SLWF), *Bemisia argentifolii* Bellows and Perring (aka sweetpotato whitefly strain B, *Bemisia tabaci* (Gennadius) is an important economic pest on cotton causing lint stickiness and yield loss. Also, the pink bollworm (PBW), *Pectinophora gossypiella* (Saunders), is responsible for losses in cotton production and acreage. Control of both pests is frequently made by aerial application. A day/ night aerial application study for control of SLWF and PBW was conducted to determine if applications against both SLWF and PBW could be made successfully at the same time or if it was advisable to target specific times of day or night for each pest. Upland cotton, *Gossypium hirsutum* L. c v 'DPL 5415' was grown and divided into twelve-5.25 ac plots. There were 2 treatments, daylight or night aerial applications, 6 plots each. Fixed wing aircraft applied 6 pesticide applications, 1/week. Leaf samples to determine populations of SLWF were taken weekly for 7 weeks 24 to 96 hours post application. PBW damage was sampled by collecting 50 bolls weekly per plot For SLWF, there were no significant differences at $P \leq 0.05$ in numbers of eggs, and nymphs between day and night applications; but there were for adults at P=0.024. PBW damage to seed was 12.84 % for day and 11.33% for night insecticide applications (differences not significant). The yields were 2.37 and 2.40 bales/acre for day and night applications, respectively (difference not significant). Lint ranged from 36.55 to 37.49 % of seed cotton weight. The daylight applications impacted the adult but not the immature SLWF populations and night applications were not more effective against PBW populations. This may possibly be a result of the relatively narrow window of time in which the applications were made. The timing of applications for day and night were only two or less hours from the time of sunrise, (except 1st application). These findings are important since they indicate that both SLWF and PBW were controlled during that window and neither required applications to be made before or after sunrise.

Investigator's Name(s): D.H. Akey and T.J. Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ 85040.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Evaluation of Hot Water Treatment for Control of Silverleaf Whitefly Nymphs on Upland Cotton in a Laboratory and Field Trial in Arizona

The silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring, is a devastating pest to numerous cultivated crops in the US. A novel suggested approach for whitefly control involved 150° F water treatment of infested plants. We evaluated this approach in laboratory and field trials for silverleaf whitefly control on cotton, *Gossypium hirsutum* L. Whitefly infested individual cotton leaves, left intact on young plants, were untreated or dipped in water baths at 82° F (ambient tap water temperature), 130, 150 and 170° F for 3 seconds. Cotton leaves were killed at the 150 and 170° F temperatures. The effects of dead cotton leaf tissue and hot water treatment on silverleaf whitefly nymph mortality could not be separated. There was no visible damage to cotton leaf tissue or significantly different whitefly nymph mortality on leaves dipped in 82 or 130° F water compared with untreated cotton leaves. In the field, hot water was applied to cotton plants using stainless steel pressurized sprayers. Water in the sprayers was heated by insertion of a heated high pressure washer wand to produce water temperatures between 196 - 206° F after ca 10 minutes of heating. Temperature measurements of spray droplets at the leaf surface showed a temperature of 150° F with a continuous spray rate of 3-4 seconds/ft of cotton row. Microscopic examination revealed no visible leaf damage 90 minutes following treatment nor was any damage apparent to plants 48 h after treatment. No significant differences in silverleaf whitefly nymph mortality occurred between ambient water temperature or 150° F hot water sprays and untreated controls.

Investigator's Name(s): D.H. Akey and T.J. Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ 85040.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March - October, 1995.

Fenoxycarb, Pymetrozine (C G A-215944), and Fenpropathrin/Acephate: Rotational Use Studies for Silverleaf Whitefly Control

Small plot trials (0.01 ac) were conducted with the agents Fenoxycarb 40 W P (0.062 lbs. ai/ac), C G A 215944 50 W P (0.094 lbs. ai/ac),(known together as Sterling, and pymetrozine alone as Fulfull) and Danitol 2.4 E C (0.20 lbs. or 0.10 lbs. / Orthene 90 S (0.5 or 0.25 lbs. a i / ac) against the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring at the University of Arizona, Maricopa Agricultural Center. The adjuvant KINETIC was used in all insecticide treatments. Ten treatments including an embedded control were tested in a double tier complete random block design. A 1.5 ac control block was use for treatment comparisons. Six applications were made. Eggs and large nymphs (well-developed 3rds-red eyed pupae) were sampled at weekly intervals (post treatment 2nd week included for last treatment) following application to determine efficacy (reported as % reduction compared with block control). Rotation schemes were as follows: 1) 3 Fenoxycarb / C G A 215944, then 3 Danitol / Orthene applications, 2) 3 Fenoxycarb-full rate / C G A 215944-2/3 rate, then 3 Danitol / Orthene applications, 3) Fenoxycarb-6 applications, 4) C G A 215944-6 applications, 5) 3 Danitol / Orthene, then 3 Fenoxycarb / C G A applications, 6) 3 Danitol / Orthene, then 3 Fenoxycarb / C G A 215944, 7) Danitol / Orthene at full, half, full, then 3 half rate applications, 8) 2 Fenoxycarb / C G A 215944, 2 Danitol / Orthene, 1 Fenoxycarb / C G A 215944, and 1 last Danitol / Orthene application, 9) 2 Danitol / Orthene, 2 Fenoxycarb / C G A 215944, 1 Danitol / Orthene, and 1 last Fenoxycarb / C G A application, 10) embedded control, and 11) block control. Percent reduction of eggs for season means ranged from 86-94% for combinations and rotations of combinations. Analyses of the last half of the season applications, including samples two weeks post last application, showed percent reductions ranging from 88-96%. Pymetrozine alone had a 91% reduction and the Danitol / Orthene had 88 % reduction of eggs. Percent reduction for season means of nymphs ranged from 86-94% for combinations and rotations of combinations. Analyses of the last half of the season applications, including samples two weeks post last application, showed percent reductions ranging from 88-96%. Pymetrozine alone had a 79% reduction and Danitol / Orthene had 88% reduction of nymphs (season). These studies showed that pymetrozine, fenoxycarb / pymetrozine, Danitol / Orthene combinations and rotations provided excellent control of silverleaf whitefly immatures.

Investigator's Name(s): D.H. Akey[1], O.T. Chortyk[2], M.G. Stevenson[3] and T.J. Henneberry[1].

Affiliation & Location: [1] USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ 85040[2], USDA-ARS, Phytochemical Research Unit, R.B. Russell Agricultural Research Center, Athens, GA 30613[3], USDA-ARS, Coastal Plain Experiment Station, Tifton, GA 31793.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July - September 1995.

Sucrose Esters as Biorational Insecticides in Field Trials Against Silverleaf Whitefly *Bemisia argentifolii*

Plot trials (0.1 ac/plot) with synthetic acyl sugar esters, similar to the natural sugar esters extracted from *Nicotiana gossei* , were conducted at the Maricopa Agricultural Center, U of A, Maricopa Arizona in 1995 against the silverleaf whitefly, *Bemisia argentifolii.* Nine treatments were applied 6 times across 3 replicates. Treatments included embedded controls and an additional completely untreated check block of 1.5 acres. In similar work in 1994, 0.01 acre plots were used with 5 replicates and 1 synthetic ester was compared to the natural sugar ester. In both years, pyriproxifen was used as an efficacy standard representing an insect growth regulator insecticide. Applications were by ground at 30 gal./ac at 400 PSI via drops that sprayed upward. Efficacies were expressed as percent reduction in whiteflies from the block control. For the first three applications with sugar esters, efficacies for eggs ranged from 0 to 51 percent and for large nymphs from 0 to 20 percent. Nor were the pyriproxyfen treatments efficacious against eggs (0%) and they were not very efficacious against large nymphs (27 and 36%). However, in the second half of the season (3 applications), efficacy of synthetic sugar esters against eggs ranged from 32 to 72% but the natural sugar ester extracts gave only 5% efficacy. The pyriproxyfen standard had 51 and 72 % efficacy against eggs. Against large nymphs, synthetic sugar esters ranged from 34 to 66% efficacy and in contrast the natural sugar extract gave 95% efficacy (only tested in 1994). The pyriproxyfen against large nymphs gave 83 and 87% efficacy. Comparisons between natural and synthetic acyl sugar esters must consider production cost effectiveness against concentrations necessary to have acceptable efficacy. The most effective synthetic sugar esters were C7 and C8 chains. The tests with the synthetics was at a concentration of 0.2 or 0.3%. The test with the natural sugar extract was at 0.2%. The results from these two years of field study indicate that more comparisons will need to the made between natural acyl sugar esters and synthetic ones.

Investigator's Name(s): M.J. Ansolabehere.

Affiliation & Location: Valent USA Corporation, Fresno, CA.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: June, 1994 - October, 1995.

Silverleaf Whitefly Control in Cotton with KNACK™ Insect Growth Regulator

KNACK (pyriproxyfen) is an insect growth regulator (IGR) which is being developed in the United States for control of silverleaf whitefly, *Bemisia argentifolii*, (SLWF) in cotton. KNACK acts as a juvenile hormone mimic and causes inhibition of metamorphosis, embryogenesis, reproduction, and larval development in certain insects. In SLWF, KNACK inhibits egg hatch, either through the females or by direct contact with the egg, and suppresses adult emergence when larvae stages are affected. KNACK also exhibits pronounced translaminar movement in cotton leaves which also leads to inhibition of egg hatch and suppressed adult emergence after SLWF feeding on the lower leaf surface.

KNACK has been tested by numerous University, USDA, and private contract personnel to determine its effectiveness on SLWF. In general, KNACK provided effective SLWF control and demonstrated IGR tendencies by reducing nymphal populations of the SLWF while not affecting adult populations and producing mixed results on egg populations in small test plots. This paper will report on two separate larger size trials that were conducted by a private contractor (Arid Ag-Research, Inc.) in 1994 and 1995 in Maricopa, AZ.

The 1994 trial was not replicated and consisted of cotton blocks of 24-40" rows X 280 ft (approximately 0.5 acre) in which 4 sub-samples were taken to determine efficacy. Applications were in 20 gpa at 80 psi pressure with overhead and drop nozzles. In one block, KNACK at 20 g ai/acre was applied as a double application on 7/12 and 8/2/94. In another block, KNACK at this same rate and schedule was alternated with DANITOL® + ORTHENE® (0.2 + 0.5 lb ai/acre) on 7/22/94. Also included in the trial were blocks that consisted of standard grower treatments and an untreated control. In this trial both KNACK regimes and the standard grower treatments significantly reduced SLWF nymph and egg populations on 8/27/94 (25 days after the last application). KNACK, alone, significantly reduced nymph populations by 93% and egg populations by 87% below the untreated control on this date. KNACK, alone, did not significantly reduce adult populations in this trial, while the standard grower treatments and the KNACK/DANITOL + ORTHENE alternating treatments significantly reduce adult populations below those found in the untreated control.

The 1995 trial consisted of cotton blocks of 24-40" rows X 580 ft (approximately 1.0 acre) in which 4 sub-samples were taken to determine efficacy. Applications in this unreplicated trial were in 20 gpa at 43 psi pressure using only overhead nozzles. In one block, KNACK at 20 g ai/acre was applied as a single application on 7/20/95 with three subsequent applications of non-IGR's used in the later season (8/8, 8/25, and 9/4/95). In another block, two applications of KNACK at 20 g ai/acre were applied on 7/20 and 8/8/95 with two subsequent applications of non-IGR's used (8/25 and 9/4/95). Also included in the trial were blocks that consisted of standard grower treatments (a total of six SLWF applications for the season) and an untreated control. In this trial both KNACK regimes and the standard grower treatments significantly reduced adult, nymph and egg populations on 9/11/95 (7 days after the last application). The two KNACK regimes reduced nymph populations by 99%, adult populations by 86%, and egg populations by 93% below the untreated control on this date. The control for the various SLWF life stages in the standard grower treatment plot was similar to the two KNACK regimes.

Investigator's Name(s): C. Bradley[1], S. Wraight[2], R. Carruthers[2], B. Staton[3], S. Jaronski[1].

Affiliation & Location: Mycotech Corp., Butte, MT 59702[1]; USDA-ARS, Subtropical Agricultural Research Laboratory (SARL), Weslaco, TX 48596[2]; and USDA, APHIS, Phoenix Plant Methods Center, Phoenix, AZ 85040[3].

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: July 1993 - December 1995.

Progress in Developing a Mycoinsecticide for Whitefly Control

USDA ARS, USDA APHIS and Mycotech Corp. have collaborated since mid 1993 in developing fungal entomopathogens for whitefly control. During 1994 and 1995, Mycotech and USDA evaluated the use of fungi for whitefly control in more than 30 field trials. These trials demonstrated efficacy of a *Beauveria bassiana*-based product, Mycotrol®, and defined issues for using mycoinsecticides in whitefly management.

Nymphal whitefly population reductions of 60-90% were consistently obtained in several different crops in Texas, Arizona and California. In many cases whitefly control and crop yields were comparable to standard pyrethroid, and organophosphate treatments.

As a bioinsecticide, Mycotrol® has significant advantages compared with chemical insecticides. These include; safety, minimal worker protection and reentry requirements, minimal impact on beneficial insects and lack of insect resistance. However, users need to accommodate some biological characteristics to obtain maximum efficacy. Accommodating a fungal based product will be similar to introducing new chemistries such as IGR's, which have unique modes of action or specific application requirements.

Coverage and integration with fungicides affect efficacy of Mycotrol® more than any other factors. Mycotrol® is a contact insecticide. The active ingredient - conidia - must contact whitefly to be effective. Three spring 1995 field trials failed to achieve adequate whitefly control. Coverage monitoring showed failure to deliver sufficient conidia to the underside of leaves. Other trials conducted with commercial hydraulic and air blast spray equipment, in the same areas showed 60-70% nymphal whitefly population reductions. Mycotrol® cannot be tank mixed with fungicides, but can be applied on an alternating schedule with fungicides using a two or three day application interval.

Environmental conditions, particularly high ambient temperatures and low humidity have much less effect on efficacy than many people assume. Mycotech and USDA continue to evaluate effects of leaf surface microenvironments on efficacy. Results clearly show whitefly infection when afternoon air temperatures reach 120°F and ambient humidity is less than 30%.

Field programs have shown that Mycotrol® can be a versatile tool in whitefly management. Honeybee whole hive studies demonstrated minimal impact on pollinators. Less than 5% of individual worker bees directly sprayed with Mycotrol® at field rates showed infection and no secondary transmission was detected within hives. Impacts on whitefly predators and parasites has been evaluated in field tests in California. Levels of whitefly mortality due to predation and parasitism was unaffected by Mycotrol®. Tank mixes or alternate treatments of Mycotrol® and pyrethroids were evaluated in a number of trials. Mycotrol® and Capture® (Bifenthrin) were effective in controlling high levels of immigrating adults and a rapidly increasing nymphal populations in a trial in which populations in untreated plots reached nearly 200 nymphs per cm^2.

Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product and the use of the name by USDA implies no approval of the product to the exclusion of others that my be suitable.

Investigator's Name(s): Steve Castle, Tom Henneberry, and Dick Weddle.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Brawley, CA, and Phoenix, AZ; Imperial County Agricultural Commissioner's Office, El Centro, CA.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March, 1992 - September, 1993.

Responses of *Bemisia tabaci* Populations in Imperial Valley to Bifenthrin and Endosulfan in a Vial Bioassay

Assessment of the role of insecticide resistance in *Bemisia tabaci* population dynamics is important for a better understanding of their outbreaks in various regions. A number of bioassay methods have been used for generating toxicological data on the responses of *B. tabaci* populations to insecticides. The relevance of such data is most meaningful on a local basis only so long as different bioassay methods are used in different regions. The continued assessment of insecticide resistance in *B. tabaci* populations in those regions where monitoring programs are established is encouraged in order to stay abreast of resistance dynamics and perhaps better advise growers on wise insecticide usage. On a more general level, however, it would be of great value to be able to compare toxicological data from one region to another so as to gain insight into regional patterns of resistance and infestation levels. How would different insecticide use patterns correlate to different toxicological responses of *B. tabaci* populations, and how would different resistance levels correlate to relatively higher or lower infestations?

The vial bioassay for contact insecticides is one technique that has been used among different regions for testing whitefly adults The general availability of this procedure was made possible largely through the collaboration of FMC Corporation and their interest in preserving the long-term efficacies of their insecticide products. They provided glass vials coated with either bifenthrin or endosulfan in a series of concentrations to any interested researcher working with *B. tabaci* or other pest species. Consequently, workers in Florida, Texas, Arizona and California have collected bioassay data for these two insecticides using the same technique.

In California's Imperial Valley, monitoring responses of *B. tabaci* populations to bifenthrin and endosulfan began in March, 1992 and continued through September, 1993. More than a hundred bioassays were conducted with each insecticide on populations collected from various crops and locations throughout the valley. There was little variation between years or among locations in their responses to bifenthrin. The mean LC_{50} for bifenthrin in 1992 was 0.043 µl/vial and in 1993 was 0.039. The range of $LC_{50's}$ throughout the two years was 0.008-0.160 µl/vial. For endosulfan, higher $LC_{50's}$ were observed in 1992 than in 1993. The mean and range of $LC_{50's}$ in 1992 was 57.9 and 5.7-254.9 µl/vial, and in 1993 was 35.6 and 10.8-74.4 µl/vial.

Investigator's Name(s): Steve Castle and Tom Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Brawley, CA and Phoenix, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 - 1995.

Temporal Patterns and Host Plant Effects on Responses of *Bemisia tabaci* to Insecticides

Three years of continuous resistance monitoring of *Bemisia tabaci* populations in the Imperial Valley, CA have revealed a pattern of $LC_{50's}$ that vary according to crop and insecticide. Beginning in 1993, populations have been sampled on a year-round basis from three crops: spring cantaloupes, cotton and fall-winter cole crops. During this time, mean $LC_{50's}$ from the same crop have decreased significantly in comparisons among years. Comparisons of mean $LC_{50's}$ between host crops within a single year also reveal significant differences that are consistent from one year to the next. Fluctuations in mean $LC_{50's}$ generated by the resistance monitoring program have been most apparent for bifenthrin.

Observations of higher or lower $LC_{50's}$ for different crops have been confounded to some degree by the different growing seasons of the crops monitored for resistance. Adult whiteflies collected from broccoli in November may have a higher vigor tolerance to insecticides by virtue of more moderate temperatures and fewer stressful events such as dispersion between crops. In contrast, whiteflies in cotton occur during times of extreme temperatures and intense dispersion. To minimize the potential affect that radically different environments might have on *B. tabaci* responses to insecticides, it would be best to test whiteflies collected from different crops growing simultaneosly and during relatively low whitefly pressure so that subjects collected for testing from their respective crops would be more certain to be resident rather than transient whiteflies.

In spring 1995, adjacent plantings of kale and cantaloupe, each with their resident whiteflies, permitted comparison of responses to four insecticide treatments using the yellow sticky card bioassay technique. Adult whiteflies collected directly from each crop were bioassayed, and then greenhouse colonies were established on both cantaloupe and broccoli plants with whiteflies from both crop sources. After one week in the greenhouse, these whiteflies were tested, and subsequently the F1 generation was tested. Whiteflies collected on kale in the field were significantly (non-overlap of 95% C.I.s) less sensitive to bifenthrin than those collected on cantaloupe. When reciprocal transplants were made, whiteflies that continued to be cultured on kale remained less susceptible than those that remained on cantaloupe, whereas ones that originated on kale but were transplanted to cantaloupe became more susceptible to bifenthrin.

Investigator's Name(s): Richard B. Chalfant and Harold R. Sumner.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Performance of three sprayers were tested on cv 'Pavo' summer squash to control the silverleaf whitefly and to reduce the expression of silverleaf. Insecticides were 0.5 & 1.0 lb(AI)/acre endosulfan and 3.75 oz/acre of Provado 1.6 EC (imidacloprid), both with and without 2% Saf-T-Side oil. Sprayers were a Berthoud® air boom delivering 30 gpa at 25 psi with two air shear nozzles per row, an electrostatic air assist sprayer by Electrostatic Spraying Systems with three nozzles per row and delivering 4 gpa at 25 psi, and a hydraulic boom equipped with three TX18 hollowcone nozzles per row and delivering 30 gpa at 100 psi. Plots were three 2-row beds, 18 ft in width and 45 ft in length and were replicated 4 times in randomized complete blocks. Application dates were 13 and 19 September. Plots were evaluated on 21 September using a 0 - 10 severity index.

Severity indices in the plots treated with Provado ranged from 3.75 to 4.0 in plots sprayed with the Berthoud and Hydraulic sprayer. There were no significant differences between these two sprayers and no significant effect using oil. Severity indices using the electrostatic sprayer varied from 8.5 - 9.5 and was not differentg from the untreated check.

Plots treated with endosulfan were not significantly different from the untreated check and from one another. The lack of silverleaf reduction is attributed to a delay application due to adverse meteorological conditions.

Investigator's Name(s): Orestes T. Chortyk.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994-1995.

New Pesticidal Sucrose Esters for Whitefly Control

New types of sucrose esters (SE) have been synthesized and shown to be potent insecticides against silverleaf whiteflies. Based upon the structures of natural sucrose esters isolated from various *Nicotiana* species and which were shown to be potent whitefly insecticides, it was decided to synthesize structurally similar sucrose esters. Specific conditions were worked out for the reaction of acid chloride with sucrose to yield a series of mono-, di-, tri-, and tetra-acyl sucroses. As the active sucrose esters of *Nicotiana* species contain mainly heptanoic and octanoic acids esterified to sucrose, C_6 to C_{12} aliphatic acid sucrose esters were prepared. Capillary gas chromatography of their TMS-derivatives showed that distinct groups of isomers were produced, including mono-acyl sucrose, di-acyl sucroses, tri-acyl sucroses, etc. Evaluations of individual groups of the C_6 to C_{12} acid sucroses showed that separated diheptanoyl sucroses, di-octanoyl sucroses, and di-nonanoyl sucroses were most active against whiteflies and aphids. Of greater interest was the finding that the total SE reaction product, consisting of mono-, di-, and tri-acyl sucroses, was also very toxic against tobacco aphids, pear psylla, greenhouse whiteflies, and sweetpotato whiteflies. Thus, for example, at a concentration of 1 mg/ml of aqueous spray solution, the heptanoyl SE caused 95% mortality of adult whiteflies after 2 hrs, while the octanoyl SE product produced 99% mortality. The total heptanoyl SE product caused 95% mortality against tobacco aphids. The newly synthesized SE are as active as the natural SE against whiteflies, but can be produced in large quantities. These sucrose esters represent a new type of contact insecticide that should be more environmentally friendly than systemic insecticides, as the SE do not kill beneficial insects, such as ladybeetles.

Investigator's Name(s): C.C. Chu and T.J. Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Laboratory. Phoenix, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Endolsulfan as a Synergist to Fenpropathrin for Silverleaf Whitefly Control

The study was conducted at the USDA-ARS Irrigated Desert Research Station, Brawley, CA. It was designed to investigate the potential of developing an alternative to the mixture of fenpropathrin and acephate for silverleaf whitefly control on cotton . Fenpropathrin and acephate mixture was not included in the study because silverleaf whiteflies in Imperial Valley have not become resistant to the mixture. Cotton cultivar 'Deltapine 5461' was used in the study. Treatments were rates of endosulfan from 0.0625 lb to 1.0 AI/ac. Fenpropathrin and endosulfan alone at 0.2 and 1.0 lb ai/ac, respectively, served as treated controls. Treatments were initiated on 21 June when the average adult whitefly numbers counted using the leaf-turn method reached 4.1 adults/leaf on 20 June. The 4.1 adults/leaf was the calculated action threshold that maximizes yield that we established in our 1993 and 1994 studies. Thereafter, weekly application of the treatments were made until 2 August for a total of 7 applications. The treatments were applied with a ground sprayer equipped with three hollow cone nozzles arranged with one at the plant's top and two drop nozzles per cotton row. Drops were extended 15 inches into the canopy. The sprayer was operated at 3 mph and 105 psi which delivered 22.7 gal/ac. Leaf sampling for adults, eggs and nymphs began from 23 May until 8 August for a total of 12 times. Results showed that there were no significant differences in silverleaf whitefly immature populations densities and lint yields for plots treated with endosulfan at rates of 0.0625 to 1.0 lb./acre in combination with fenpropathrin.

Investigator's Name(s): Wayne E. Coates and John C. Palumbo.

Affiliation & Location: OALS, University of Arizona, Tucson, AZ and Entomology Department, University of Arizona, Yuma Valley Agricultural Center, Yuma.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: April - June 1995.

Deposition, Off-Target Movement and Efficacy of Capture and Thiodan Applied to Melons Using Several Application Technologies.

Adult and immature sweet potato whiteflies strain B., *Bemisa tabai.,* feed on the ventral surfaces of cantaloupe leaves, *Cucumins spp.*, where deposition from conventional spray technologies is inadequate. An Electrostatic Spraying Systems sprayer (with the charging circuit on and off), a Micromax CDA without air assist, a DeGanya with air assist, and a conventional twin nozzle system were field tested to assess deposition efficiency, whitefly control, and cantaloupe yield, as well as drift and off-target deposition.

Ventral deposition was several times less than dorsal deposition for all systems. The ESS-on and DeGanya had the highest, and the conventional the lowest, ventral deposition efficiency. Ventral efficiency decreased as the season progressed and the canopy closed, with the ESS systems showing greater decreases in efficiency than the Deganya.

For the first two application dates, the ESS-on and ESS-off were associated with greater insect control than the CDA or conventional systems, four days after treatment (DAT). Later in the season no differences were detected. Insect control seven DAT was not significantly different among treatments. Overall, cantaloupe yields were not significantly different than the untreated control. The ESS-on and ESS-off systems, however, were associated with significantly greater yields of #12 melons, than the untreated control.

Drift and off-target deposition were significantly greater for the Deganya than any other system, except the conventional. Drift was significantly less for the ESS systems than either the conventional or the DeGanya.

Because there were no strong differences in sweet potato whitefly control and cantaloupe yield among systems, and because ventral surface deposition was minimal and declined with canopy closure for all systems, further development of spray technology is warranted.

Investigator's Name(s): T.J. Dennehy, Livy Williams III, June S. Russell, Xiaohua Li, and Monika Wigert.

Affiliation & Location: University of Arizona, Department of Entomology.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Monitoring and Management of Whitefly Resistance to Insecticides in Arizona

Monitoring of whitefly resistance in the major cotton-producing areas of Arizona confirmed the presence of an over 100-fold resistance to the mixture of Danitol® + Orthene® (fepropathrin + acephate). Strong evidence was found of cross-resistance affecting the other principle pyrethroid insecticides used to control whiteflies (Asana®, Capture®, Karate®). Susceptibility to Ovasyn® varied widely in leaf-disk bioassays; lesser variation was observed in whitefly susceptibility to endosulfan. A provisional resistance management strategy (IRM) for Arizona whiteflies was formulated and evaluated in a 200 acre field trial in 1995. A key element of the strategy was diversifying as much as possible the insecticides used against whiteflies. Contrasts of this (rotation) strategy with a more conventional (less diverse) regime showed that rotation slowed but did not prevent resistance from developing. By seasons end, both the IRM and conventional plots had very high and comparable levels of resistance to Danitol® + Orthene®. This large field trial illustrated clearly the seriousness of the whitefly resistance problems faced in Arizona. It showed that whitefly populations cannot be managed effectively solely with the products currently registered for this purpose in Arizona. The large shift to lower susceptibility took place with as few as 3 insecticide treatments. In concert, our field and laboratory results indicate unequivocally that Arizona growers will be forced by resistance to greatly reduce reliance on pyrethroid insecticides in the coming season. This underscores the urgency for obtaining approval of novel new insecticides for whitefly control and for deploying new products within the framework of a resistance management strategy that limits their use.

Investigator's Name(s): T.J. Dennehy[1] and Larry Antilla[2].

Affiliation & Location: [1]University of Arizona, Department of Entomology, Extension Arthropod Resistance Management Laboratory, Tucson, AZ; [2]Arizona Cotton Research & Protection Council, Phoenix, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994 - 1995.

Whitefly Resistance to Insecticides in Arizona

Monitoring of Arizona whitefly resistance to insecticides in 1994 and 1995 demonstrated a >100-fold resistance to what has been one of the most effective insecticide mixtures for controlling whiteflies: Danitol® + Orthene®. Evidence also pointed to cross-resistance to other synergized pyrethroids used to control whiteflies. Statewide monitoring indicated that growers in some areas of Arizona are running out of effective registered insecticides for controlling this pest. These findings have lead to intensive inter-agency collaborations in Arizona aimed at: obtaining registration of new selective insecticides and integrating them into a biologically-based whitefly management program; formulation, demonstration and area-wide implementation of integrated resistance management programs; and statewide education of cotton growers in whitefly management.

Investigator's Name(s): T.J. Henneberry[1], L. Forlow Jech[1], and H.H. Perkins, Jr.[2]

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 4/1 - 10/1/1995.

Silverleaf Whitefly and Sticky Cotton Relationships

In 1995, studies were conducted at the University of Arizona, Maricopa Agricultural Center, Maricopa, AZ to determine the effect of cotton cultivars, plant density and insecticide treatment on whitefly populations and sticky cotton. The experiment was conducted in a split-split plot design with cultivars Pima S7, Delta and Pineland (DPL) 5415 and DPL 50 as whole plots, insecticide-treated and untreated as sub-plots and plant density (10 or 40 thousand plants per acre) as sub-sub plots. Insecticides were applied to experimental plots specifically for whitefly control on 25 July (Provado), 2 August (Provado), 8 August (Capture plus Acephate), 22 August (Capture plus Acephate) and 6 September (Provado). All plots were also treated with Lorsban plus Acephate for other insect pests on 31 July, 22 and 29 August. Adults were sampled weekly from 27 June to 11 September using the leaf-turn method. Nymphs were sampled weekly by picking 15 leaves at random from each plot and all nymphs were counted on a 3.88 cm^2 leaf disk from each leaf with the aid of a microscope. Results for nymphs are expressed as nymphs/cm^2 of leaf area. Seed cotton was randomly picked from plants in each plot (20 bolls) on 20 September to analyze for cotton lint stickiness using the thermodetector method. Results showed that plant density had no effect on seasonal average numbers of whitefly adults or nymphs. Seasonal average numbers of adults were highest (33.6 ± 6.8) in untreated Pima S7 plots followed by DPL 5415 (25.9 ± 10.7) and DPL 50 (16.7 ± 6.8). Numbers of adults in insecticide-treated Pima S7, DPL 5415 and DPL 50 plots were 9.9 ± 2.6, 4.8 ± 1.2, and 5.8 ± 1.5, respectively. Numbers of nymphs/cm^2 of leaf area were 6.8 ± 2.6, 7.2 ± 3.0, and 7.3 ± 2.9 for untreated Pima S7, DPL 5415 and DPL 50 cotton, respectively and 1.2 ± 0.3, 1.3 ± 0.4, and 1.5 ± 0.4 for insecticide-treated cottons. There were no significant differences in cotton lint thermodetector stickiness ratings between plant densities or cultivars. The average thermodetector ratings for untreated cotton over all densities and cultivars was 13.2 compared with the average rating of 3.8 for insecticide-treated plots. The rating of 3.8 is considered non-sticky lint and 13.2 light stickiness.

Investigator's Name(s): T.J. Henneberry[1], D.H. Hendrix[1], H.H. Perkins Jr.[2], H.M. Flint[1], L. Forlow Jech[1] and R.A. Burke[1].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1991-1995.

Silverleaf Whitefly Honeydew and Sticky Cotton Relationships

Trehalulose and melezitose produced by silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring accumulated in cotton lint in open cotton bolls on plants and on lint on harvested bolls in trays suspended in infested plants. Amounts accumulated were positively correlated to increasing numbers of exposure days. Fructose, glucose and total reducing sugars increased but results were variable. Probably because these sugars, although found in honeydew, also normally occur in cotton lint. Minicard sticky cotton ratings were positively correlated to increased amount of all sugars tested. Rainfall (4.8 cm in a 48 h period) reduced amounts of all sugars and minicard sticky cotton ratings. Accumulated sugars and minicard sticky cotton ratings were reduced in insecticide-treated compared to untreated fields. Trehalulose, melezitose, fructose and glucose accumulated on Clear Plastic-wrapped styrofoam balls in *B. argentifolii* infested cotton fields were positively correlated to exposure time in the fields. Amounts of all sugars, in general, were higher on Clear Plastic-wrapped balls placed at the middle and bottom of the plant as compared to the top of the plant. Amounts of trehalulose, melezitose, and fructose, but not glucose, were significantly higher on lint from bolls at plant nodes 9 to 14 as compared to nodes 15 to 20.

Investigator's Name(s): T.J. Henneberry[1], D.H. Hendrix[1], H.H. Perkins Jr.[2], S.E. Naranjo[1], H.M. Flint[1], D.H. Akey[1], L. Forlow Jech[1] and R.A. Burke[1].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1991 - 1995.

Silverleaf Whitefly Populations and Relationships to Sticky Cotton and Cotton Yields

Numbers of *Bemisia argentifolii* Bellows and Perring were lower in experimental plots in 1991 than 1993 or 1994 and lower in 1994 than in 1993. Adults in black pan samples were positively correlated to numbers of eggs and nymphs and nymphs were positively correlated with eggs from whole leaf samples in 1991 and from 3.88 cm^2 leaf discs in 1993 and 1994. In 1991, minicard sticky cotton ratings (0.0 to 0.3) for lint were low but positively correlated to numbers of *B. argentifolii* adults, adults and nymphs, but not nymphs alone. In 1993, *B. argentifolii* numbers and minicard sticky cotton ratings were higher in untreated plots than in plots treated with 3 or 6 insecticide applications during the season. Similar results occurred in 1994 when 6 insecticide applications were applied, three specifically for *B. argentifolii* control. Trehalulose and melezitose were correlated positively to minicard sticky cotton ratings in 1993 and thermodetector ratings in 1994. *B. argentifolii* adults, nymphs, and adults plus nymphs also were correlated to the insect-produced sugars, trehalulose and melezitose in both years. *B. argentifolii* populations were significantly and negatively correlated to cotton lint yields in 1994, but not in 1991.

Investigator's Name(s): A. Rami Horowitz[1], Gadi Forer[2] and Isaac Ishaaya[1].

Affiliation & Location: Department of Entomology, Agricultural Research Organization, The Volcani Center, Bet Dagan 50250, Israel[1]. Cotton Production and Marketing Board, Herzliyya-B 46103, Israel[2].

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1990 - 1995.

Since the 1930s, the genus *Bemisia* has been known in Israel as a sporadic pest to various vegetable crops. An outbreak of *Bemisia* populations occurred in 1976 and since then, it has been considered a major pest of cotton, vegetables and ornamentals.

Spring populations develop on potatoes sunflowers and cucurbitaceous crops. Thereafter the whiteflies migrate to cotton fields and establish their first cotton generation. High populations develop mainly from the second half of July through August and September. In 1988, when an extremely high population developed, the cotton yield was considerably reduced.

The Israeli IPM-IRM strategy, introduced in cotton in 1987, is focused primarily on controlling *Bemisia* with novel insecticides, especially the IGRs pyriproxyfen and buprofezin. A rotation scheme has been established, in which each insecticide is used once during one pest-generation and is followed by another pesticide with a different mode of action. The use of conventional insecticides, including pyrethroids, is complementary and is applied only on special occasions. Extensive resistance-monitoring programs are conducted. Base-line bioassays for susceptibility of key pests to the most important novel insecticides were carried out prior the resistance-monitoring in field populations.

The seasonal trends in susceptibility to buprofezin and pyriproxyfen in *Bemisia* field populations were monitored from June (prior to treatment) through late summer when a slight increase in tolerance was observed. Due to the restricted use of these two novel compounds, and the consequent reduction in selection pressure, they could be applied also in the following season while the pest populations maintained their susceptibility to them. In contrast, high to moderate resistance levels to pyriproxyfen and buprofezin were detected in *Bemisia* in some ornamental greenhouses following successive applications of these materials.

In spite of the IRM strategy, a slight to moderate level of resistance to pyriproxyfen was observed in some locations following six years of IGR use, while in most locations, the susceptibility of populations to pyriproxyfen and buprofezin has been maintained. Consequently, an adaptation to the change in the susceptibility of *Bemisia* to IGRs will be considered.

The extent of future use of both IGRs in the various cotton regions in Israel will be determined according to the results of resistance monitoring early in the cotton growing season. Heretofore unused chemicals (such as diafenthiuron, novaluron, imidacloprid and acetmiprid), will be incorporated as pesticides against whiteflies when the present insecticides will loose their efficacy for controlling the whitefly.

Investigator's Name(s): D. Michael Jackson[1], A.M. Simmons[1], O.T. Chortyk[2], M.G. Stephenson[3], A.W. Johnson[4], C.D. Harlow[5], and V.A. Sisson[5].

Affiliation & Location: [1]USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC; [2]USDA-ARS, Russell Research Center, Athens, GA; [3]USDA-ARS, Coastal Plain Experiment Station, Tifton, GA; [4]Clemson University, Pee Dee Research & Education Center, Florence, SC; [5]N. C. State University, Tobacco Research Station, Oxford, NC.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Production of Biorational Insecticides by *Nicotiana* species

Sucrose and glucose esters are produced by several species of plants in the family Solanaceae, including *Nicotiana*. Recent experiments documented the efficacy of sugar esters as biorational insecticides for control of soft-bodied insects such as whiteflies and aphids, and there is interest in the commercial development of natural and synthetic sugar esters for this purpose. The sugar esters from *Nicotiana gossei* have been patented as a biopesticide. The purpose of this study was to assess the potential of *Nicotiana* species for production of sugar esters in the field.

Eight *Nicotiana* species were grown: *N. amplexicaulis* (accession 65), *N. glutinosa* (acc. 24), *N. gossei* (acc. 26), *N. hesperis* (acc. 67), *N. langsdorffii* (acc. 28A), *N. noctiflora* (acc. 35 & 35A), *N. palmeri* (acc. 39), and *N. trigonophylla* (acc. 60). Seedlings were transplanted into replicated (4) field plots of 120 plants each at Florence & Charleston, SC and Tifton, GA during 1995. Cultural practices typical for flue-cured tobacco production were employed at each location. Fifty plants/plot were cut off just above the ground, weighed, and dipped into isopropanol to remove cuticular leaf components. Also, five 2-cm diam leaf plugs/plot were dipped 10 times in methylene chloride to provide analytical samples. Sugar esters were analyzed by glass capillary gas chromatography using published techniques. Plants were allowed to regenerate, and two additional harvests were made for each species at each location.

Biomass production levels were consistently higher at Charleston than at the other locations. Overall, *N. gossei*, *N. langsdorffii*, *N. noctiflora*, and *N. amplexicaulis* produced the most green-weight biomass/ha. All *Nicotiana* species survived transplantation well, but survival was poor for some species after the second cutting (especially *N. gossei* and *N. glutinosa*). Excessive rainfall caused drowning and led to weed problems in all fields. The third harvest provided little biomass at any location because of poor survival and growth. The highest average production of sugar esters per leaf area was for *N. trigonophylla* (162.7g/cm^2) and *N. palmeri* (94.7g/cm^2). Sucrose esters predominated over glucose esters in all species except *N. gossei* and *N. amplexicaulis*. In general, sugar ester levels increased with subsequent harvests.

The production, composition, and insecticidal activities of the sugar esters from different *Nicotiana* species vary, and some species have more potential than others as candidates for commercial production of bioinsecticides. Despite being a poor yielder of green biomass, *N. trigonophylla* produced the highest levels of crude cuticular extract at 8.9 g & 9.1 g/50-plant plot for harvests 1 & 2, respectively. This compared to *N. gossei*, which produced only 3.8 g & 5.5 g/plot for the same two harvests. After purification, *N. trigonophylla* yielded 6.2 g & 6.2 g of pure sugar-ester biorational/plot for harvests 1 & 2, respectively, compared to yields of 0.8 g & 2.3 g/plot for *N. gossei*. Based on a planting density of 17,600 plants/ha used in this study, *N. trigonophylla* produced 2.2 kg of pure sugar-ester biorational/hectare. This was four times the production of *N. gossei*. The sugar ester biorational from *N. trigonophylla* is active against aphids and whiteflies, and it is comparable to the biorational material from *N. gossei*. The ease of extractibility and separation of sugar esters from other surface components also vary among *Nicotiana* species. Because the surface component profile of *N. trigonophylla* is less complex than that of several other *Nicotiana* species, the sugar ester fraction is comparatively easy to fractionate. Therefore, *N. trigonophylla* appears to be a superior source of sugar esters for use as a biorational insecticide.

Investigator's Name(s): Stefan T. Jaronski, Jeffrey C. Lord, and Ron Paden.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: April - July 1995.

Bemisia argentifolii Control in Melons with Mycotrol WP®

In the spring of 1995 three small plot trials of Mycotrol WP®, a *Beauveria bassiana*-based insectice were run on cantaloupe in the southwestern irrigated desert. The target of the trials was *Bemisia argentifolii* (silverleaf whitefly). Goals were to examine rate effects of Mycotrol® used alone, to optimize tractor-mounted hydraulic spray application, and to ascertain overall efficacy when used in tank-mix combination with bifenthrin (Capture 2EC), and fenpropathrin (Danitol 2.4EC).

BRAWLEY, CA: Treatments were untreated control (UTC), carrier (0.04% Silwet L77) only, Mycotrol WP® at 0.125, 0.25 and 0.5 lbs per acre (GPA). Seven weekly applications were made with a Solo backpack airblast sprayer at 30 GPA (treatments 1-5) or 50 GPA (treatments 6-7).

Despite confounding adult immigration into the plots, a 0.5 lb rate of Mycotrol (1×10^{13} conidia/acre), was superior to lower rates, giving 53% (all nymphs) to 74% (large nymphs + pupae only) control, vs. 38% and 53% control of all and large nymphs by the lowest rate. Daily maximum air temperatures exceeded 35°C. during the second half of the trial, while ambient humidities fluctuated between a high of 60% and a low of 17%. *Beauveria* conidia had a half-life on leaf undersides of 4 to 9 days, inferring that at least weekly treatment with fungus is necessary for maximum control.

EL CENTRO, CA: Treatments were UTC, carrier (0.04% Silwet L77) only, Mycotrol WP® at 0.25 and 0.5 lbs per acre (5×10^{12} and 1×10^{13} conidia/acre, resp.), bifenthrin (Capture 2EC) at 0.02 lb ai/acre, and a tank mix of 0.5 lb Mycotrol WP + 0.02 lb ai Capture per acre. Applications were made with a Solo backpack airblast sprayer at 30 GPA There was little difference in efficacy between the 0.25 lb and 0.5 lb Mycotrol treatments. A very low rate of bifenthrin (one-fourth the recommended field rate) gave 75% (small and large nymphs) - 78% (large nymphs/pupae only), control by Day 28. This level of control was not enhanced by the tank-mix with *Beauveria*. We believe the observed efficacy of bifenthrin at such a low rate demonstrates the high efficiency of air blast sprayers.

YUMA, CA: Treatments were UTC, carrier (0.05% Silwet L77) only, 0.02 lb ai Danitol 2.4EC, lb Mycotrol WP, Mycotrol (0.5 lb) + Danitol 0.02 lb), 0.5 lb ai Capture 2EC, and Mycotrol (0.5 lb) + Capture (0.5 lb ai). Applications were made May 18, June 1, 5, 9, 15 and 22 by Tactor-drawn hydraulic sprayer. Over the course of the trial, gallonage was increased from 40 to 100 GPA while pressure was reduced from 120 to 80 psi. The nozzle arrangement on the horizontal boom was changed from 2 drop nozzles (D1/13 hollow cone) on each side directed toward the bed, to 7 nozzles per bed with 4 inch spacings, alternately directed forward and backward at ca. 30 degree angles, and, for the final 3 sprays, to the same boom configuration with D2/33 full-cone nozzles. After the final 3 weekly applications, the 0.5 lb rate of *Beauveria* gave control equal to a 0.2 lb ai rate of profenpathrin, but was inferior to a low rate of bifenthrin (0.05 lb ai/acre). Mycotrol-chemical tank mixes improved the performance of profenpathrin (from 62% to 85% control of large nymphs/pupae) but not bifenthrin.

Modification of the spray boom to one having seven D2/33 nozzles per bed with a spacing of 4 inches, with the nozzles alternately arranged forward and backward at about a 30 degree angle and delivering 90 GPA at 80 psi, gave much better under-leaf coverage than other arrangements.

Investigator's Name(s): Walker A. Jones[1], W.C. Warfield[1], M. Ciomperlik[2], M. Rose[3] and J. Goolsby[2].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Comparative Biology of a Uniparental and a Biparental *Eretmocerus* spp.

An array of parasitoids of *Bemisia tabaci/argentifolii* are being evaluated for their potential for use as biological control agents, either through release for establishment or for manipulative methods. Basic biological attributes of two of the available species of *Eretmocerus* (Hymenoptera: Aphelinidae) are reported on here.

A strain of *Eretmocerus mundus* (M92014), originally collected from Spain by Alan Kirk and Lerry Lacey (USDA, ARS, European Biological Control Lab.), is a biparental species that has recently been identified as possessing significant tolerance to a variety of insecticides and thus merits closer scrutiny. This species also is currently being released for establishment as well as being evaluated in augmentation trials in Texas and California. The second species, originally collected at College Station, Texas (M94002) by Mike Rose and Steve Stauffer, is of biological and ecological interest because it reproduces parthenogenetically. Development rate, fecundity, and longevity of each species were studied at 27°C, 50-55% RH.

Parasitoids were maintained on *B. tabaci*, biotype B (= *B. argentifolii*), at USDA, APHIS, Mission, TX on *Hibiscus rosa-sinensis* var. Kona Pink. Evaluations were conducted at the USDA, ARS, SARL, Biological Control of Pests Research Unit, Weslaco, TX. Ca. 250 whitefly immatures were established on the underside of sweet potato leaves by confining adults in clip cages for several hours. Leaves were previously excised and rooted in hydroponic solution within plastic tubes. Individual, newly emerged female parasitoids were first exposed to two males and observed until apparent mating (*E. mundus* only). Eleven females of each species were successfully evaluated. Each female was placed with an infested leaf in a large ventilated Petri dish. Leaves with exposed hosts were changed every other day until parasitoid death. Days to emergence and number and sex of progeny were recorded. Some progeny from each species were held individually in gelatin capsules containing honey to measure longevity.

The results accrued to date show that the Spanish *E. mundus* required a mean of 14.3 d to develop from egg to adult emergence (n = 1003); the uniparental *Eretmocerus* sp. took significantly longer at 19.8 d (n = 404). By comparison, the local *Eretmocerus* sp. develops in 17 days at 27°C. Female longevity for the uniparental *Eretmocerus* when fed honey only was 4.4 d (n = 358, range = 1-17), compared to 8.7 d (n = 266, range = 1-20) for *E. mundus*. Female longevity was significantly greater when exposed to unlimited hosts: 23.8 d and 16.8 d for the parthenogenetic *Eretmocerus* and *E. mundus*, respectively The parthenogenic species averaged 447.3 female progeny per lifetime, while the biparental *E. mundus* produced a mean of 338 females. Successfully mated *E. mundus* produced females only during the first 8-10 days of life, while the parthenogenetic species produced their female progeny throughout their life. The female production pattern of *E. mundus* was similar to that for the previously studied *Eretmocerus* sp. from Texas. Percent successful emergence was 96.2 % for the parthenogenic species, 93.5 % for *E. mundus*.

Investigator's Name(s): Walker A. Jones[1], W.C. Warfield[1], M. Ciomperlik[2] and M. Rose[3].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Temperature Effects on Foraging Efficiency of Four Native and Exotic Parasitoids

There are many known species of parasitoids of the *Bemisia tabaci/argentifolii* complex, and several have been imported for release and establishment in the United States. Comparative evaluation of each species' potential may include laboratory studies to screen which species should be targeted for larger scale studies. There are many factors that determine the comparative efficiency of parasitoid species. Among the fundamental traits is their ability to successfully parasitize hosts within specific temperature ranges.

Four species of parasitoids were tested: (1) *Eretmocerus* sp. from south Texas, (2) *Eretmocerus mundus* (M92014) from Spain, (3) *Encarsia pergandiella* (light form) from Texas, and (4) *Encarsia* sp. nr. *pergandiella* (M94055), a parthenogenetic species from Brazil. Temperatures were 20, 25, 30, and 35°C. Progeny production of individual females was measured for the first two days following emergence. Each test female was isolated prior to emergence, then exposed to 2 males for 2 hours before being exposed to hosts. Prior to testing, parasitoids and hosts were maintained at 27°C. Following exposure, hosts were incubated at 27°C. Each female and accompanying males were aspirated into a large ventilated Petri dish containing a rooted sweet potato leaf infested with 10-d-old host nymphs (2nd-3rd instars at 27°C). Fecundity was based on counts of parasitoid pupae. Successfully emerged progeny were counted and sexed. Mean 2-day progeny production for each species at 20, 25, 30 and 35, respectively was:

Eretmocerus sp. (TX); 17.9, 55.7, 71.8 & 68.8
Eretmocerus mundus (Spain); 22.3, 53.9, 85.7 & 82.0
Encarsia pergandiella (TX); 18.1, 36.6, 55.9, & 46.0
E. pergandiella (Brazil); 11.6, 19.2, 36.1, & 30.0

Eretmocerus mundus from Spain generally exhibited the highest fecundity across the various temperatures during the first 2 days of adult life. Overall, the Brazil uniparental *Encarsia* was not as productive across all temperatures in comparison with the other 3 species. Each *Eretmocerus* spp. demonstrated higher initial fecundity than the *Encarsia* spp. These studies are being expanded to include lower temperatures. Possible differences in host stage preference among parasitoid species may have an influence on the results.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994 - 1995.

Using Admire on Desert Vegetable Crops

For lettuces and cole crops there are three techniques that have yielded good efficacy and minimal mechanical crop damage. 1) Sub-seed furrow applications of Admire have been shown to be very effective when injected into the soil 1.5-3.0 inches below the seed line just prior to planting. 2) For transplanted cauliflower, Admire has demonstrated efficacy when injected into or just below the soil zone where the transplant plug will be placed and the cauliflower's roots will be concentrated. 3) Soil-surface, banded applications have been shown to be effective on direct-seeded lettuce. However, research suggests that whitefly control using soil-surface banded applications may diminish slightly towards the end of the season, resulting in slight yellowing of some lettuce varieties. Soil-surface applications should be applied preemergence as a 2.0-3.0 inch band over each seed line. The material should be hydrologically incorporated within 24 hours of application, using overhead sprinkler irrigation. University research has shown that soil-surface banded applications not incorporated with sprinkler irrigation but via furrow irrigation did not provide adequate efficacy. At present, the University of Arizona does not recommend side-dressing of Admire in lettuce or cole crops.

As with lettuce and cole crops, Admire has been shown to effectively control whiteflies when injected at 16 fluid ounces per acre (80 inch rows) 3.0 inches below the seed line (sub-seed furrow) just prior to planting melons. In commercial settings it has also been effective at controlling whiteflies when applied through a low pressure drip irrigation system. Because whitefly pressure can be especially intense on fall grown melons, the University of Arizona does not recommend use of Admire on melons planted between May 1 and October 1 at elevations below 700 feet without augmenting control with foliar adulticides.

Produce and melons grown in the low-desert area of Arizona where a multi-cropping system predominates can be categorized as being at a low or high risk of whitefly infestation. Growers should consider not using Admire on crops grown under low risk situations. Alternative classes of insecticides have proven effective for whitefly control on lettuce, cole crops and melons under low risk situations. In addition there are several chemical use strategies that should alleviate imidacloprid selection pressure on whiteflies to combat resistance development.

Lettuce and Cole Crops
Low Risk: Crops planted in October or later when temperatures are lower and there is no significant host source (i.e. alfalfa, cotton or melons) of whiteflies within a one-mile radius.
High Risk: Crops planted in August-September, or later and that are near a significant whitefly source when temperatures are high.

Melons
Low Risk: Melons planted in early spring during cool temperatures.
High Risk: Late spring and fall plantings.

Chemical Use Strategies
- Consider using foliar materials for whitefly control under low risk situations.
- If possible, avoid using imidacloprid (Admire or Provado) in cotton.
- If by the thinning and heading stages, whiteflies are building up on fall produce or fall melons, consider applying a non-imidacloprid foliar insecticide to reduce the number of possible imidacloprid tolerant individuals.
- Avoid using Admire after whitefly pressure subsides and no potential exists for later infestations of aphids.

Investigator's Name(s): M. A. Latheef[1] and Dan A. Wolfenbarger[2].

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: January 1, 1995 - June 30, 1995.

Toxicity of Mixtures of Fenpropathrin and Bifenthrin with Acephate Against Resistant and Susceptible Strains of Sweetpotato Whitefly

Toxicity of fenpropathrin and bifenthrin alone and each in mixtures with acephate to adults and nymphs of a resistant (R) and a susceptible (S) strain of sweetpotato whitefly was studied using glass vial bioassay and foliar sprays. With glass vial bioassay, LC_{50}s for mixtures of fenpropathrin with acephate in 1: 2.5 ratio were 35.1 and 0.16 µg/vial for R and S strains, respectively. LC_{50}s for mixtures of bifenthrin with acephate in 1: 6.25 ratio were 2.27 and 0.07 µg/vial for R and S strains, respectively. These values were significantly different. Regardless of the strain, toxicity of foliar sprays of compounds alone and mixtures of compounds to small nymphs was not significantly different. Mixtures of compounds significantly increased the mortality of S strain large nymphs compared to compounds alone and suggest synergism. However, neither compounds alone nor mixtures of compounds significantly influenced mortality of S strain large nymphs. Regardless of the strain, acephate provided the lowest nymphal mortality. Neither volumetric spray application rate (28 and 46.7 L/ha) nor spray droplet size (average $D_{V0.5}$ = 160 and 310 µm) significantly influenced toxicity of mixtures of compounds to R nymphs. Regardless of the mixtures of compounds, sprays with large droplet spectrum provided significantly greater mortality of S nymphs than did sprays with small droplet spectrums. The data suggest that an understanding of the resistance level of SWF populations to mixtures of pyrethroids with acephate may be important in evaluating efficacy and to use an appropriate application technique for maximizing control of the pest.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Bioassays of Insecticidal Activity of Natural and Synthetic Sugar Esters Against *Bemisia argentifolii* (Homoptera: Aleyrodidae)

Insecticidal activities of natural and synthetic sugar ester (SE) isolates of *Nicotiana* spp. were tested against the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring in the laboratory. Whiteflies were maintained in an air-conditioned greenhouse on potted tomato, collard, salvia, eggplant, hibiscus, and sweet potato plants. Cuticular SE was extracted from *Nicotiana* spp. with isopropyl alcohol and synthetic SE prepared by reacting sucrose with acid chlorides SE concentrates were dissolved in 20x of acetone (wt.:vol.) with which aqueous dispersions of SE isolates were prepared for either spray or leaf-dip application. *Adult Bioassay.* Adult whiteflies (20-50) were immobilized by allowing them to alight on 4 cm^2 of yellow sticky polyethylene cards. *Trial 1.* Whitefly bearing cards were sprayed to runoff with 2 concentrations (0.5 and 1 g/liter) of 7 SE isolates using a hand spray pump. Cards were air-dried for 1 h and then held in a plastic ice chest (100% RH) for 4 h. Whiteflies were examined under a stereoscopic microscope and considered dead when no movement was observed after gentle probing with a camel hair brush. *Trial 2.* Whitefly-bearing sticky cards were sprayed as above with 0.25, 0.5, 1 and 2 g/liter *N. gossei* SE or with 2-ml of each solution using a Potter Spray Tower at 7 kg/cm^2 pressure. *Nymph Leaf-dip Bioassays.* Young whitefly-free sweet potato leaves (*Trial 1, Trial 3*) or tomato leaves *(Trial 2*) were collected and inserted into individual root cubes petiole down in plastic trays immersed in nutrient solution. Whiteflies (40-60 per leaf) were introduced onto the leaves in a large cage for an oviposition period of 24 h. Whiteflies were vacuumed off and egg-bearing leaves incubated in whitefly-free cages for 10 d. Leaves (*Trial 1*) bearing mostly 2nd instars were dipped in appropriate SE concentrations for 5 s, then air-dried for 1 h on paper towels. Mortality was examined 4 days after treatment. *Trial 4.* Second instar nymphs on sweet potato leaves were treated with 1 g (AI)/liter *N. gossei* SE isolate as above, or by spraying with the Potter Spray Tower (2 ml solution at 0.7 kg/cm^2).

SE isolates of *N. amplexicaulis, N. glutinosa, N. langsdorffii* and *N. trigonophylla,* and *N. gossei,* induced strong mortality responses in immobilized whitefly adults sprayed to runoff. In contrast, mortality responses of adult *B. argentifolii* to *N. gossei* SE isolate applied with the Potter Spray Tower were feeble. Rate response was significant ($P < 0.001$), but only between the 0.5 and 1 g/liter concentrations. These results indicated that complete coverage of adult whiteflies with these materials was necessary to achieve high levels of adult mortality. Significant differences in mortality response of second instar *B. argentifolii* to both rates of 11 natural SE isolates of *Nicotiana* species were observed in *Trial 1* ($P < 0.001$). SE isolates of *N. gossei* and *N. palmeri* caused greatest mortality (96.7 and 89.9% respectively, at 1 g/liter), whereas, highest mortality (89.6%) was seen with *N. gossei* at 0.5 g/liter. Mortality response of nymphs to other materials tested in was weak (18.2-58.8%). Greater than 95% mortality of second instar nymphs was observed in response to SE isolates at 1 g/liter of *N. amplexicaulis, N. glutinosa, N. langsdorffii, N. trigonophylla,* and *N. gossei* when tested on tomato leaves (*Trial 2*) SE isolate from *N. glutinosa* 24A caused only 31.2% mortality to second instar whiteflies, probably due low (11%) content of sucrose esters. Mortality response of second instar nymphs exposed by leaf-dip to three concentrations of *N. gossei* SE and the synthetic SE was statistically indistinguishable (*Trial 3*), a strong rate response was observed for both materials ($P < 0.001$). Mortality of whitefly nymphs was significantly less when nymphs on the leaves were sprayed than when dipped, for all 3 rates of *N. gossei* SE, again demonstrating the importance of good spray coverage.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Insecticidal Activity of Natural and Synthetic Sugar Esters Against *Bemisia argentifolii* (Homoptera: Aleyrodidae) on Field Tomato Plants

Insecticidal activities of natural and synthetic sugar ester isolates of *Nicotiana* spp. were tested against the silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring on field tomato plants. Twenty-three grams of SE isolate were dissolved with 100 ml of acetone, 100 ml of methanol, and 28 ml of Latron CS-7 spray adjuvant (Rohm-Haas, Philadelphia, PA). The SE solution was then poured into rapidly stirred water (7.6 liter), to make a 3 g (AI)/liter (0.3%) spray dilution. Tomato ('Agriset') seedlings (15-20 cm high) were exposed to a greenhouse colony of *B. argentifolii* for 5 d to infest with whitefly eggs. Seedlings were planted on 27 Feb 1995 in sandy soil at SWFREC, 46 cm between in 81 cm wide beds fumigated with 220 lb methyl bromide/choropicran 67/33 and covered with black polyethylene mulch following standard procedures for southwest Florida staked tomato production. A randomized complete block design was used with 4 replications and treatments included 5 SE isolates and 1 untreated control. Blocks ran east and west and plots were 7.4 m long and 3 rows (1.8 m centers) wide. Plants were sprayed weekly for 8 weeks starting the 4th week after the transplanting. Applications were made with a tractor-drawn high clearance sprayer fitted with 4-8 Albuz® "yellow" hollow cone ceramic nozzles per row (depending on plant height), operating at 14 kg/cm pressure and 3.2 km/h (2 mph). Delivery rates were 309 liter/ha (33 gal/a) with 4 nozzles (first 3 weeks), 570 liters/ha (61 gal/ac) with 6 nozzles (4th week), and 758 liters/ha (81 gal/ac) with 8 nozzles (remaining 4 wk). A pre-treatment sample of whitefly nymphs and pupae was taken on 17 March 1995. Post-treatment samples (8) were taken weekly thereafter of whitefly adults, small nymphs (first and second instars), small nymphs (third and fourth instars), pupae and parasitized pupae. Whitefly adults from 6 plants in the center row in each plot were sampled by striking a black baking pan (24 by 33 by 2.5 cm) against the vegetation and counting whiteflies trapped in a thin film of soybean oil and detergent mixture (oil:detergent = 30:1, vol.:vol.) coating the bottom. Whitefly immatures were sampled from 4 randomly selected plants of each of the 3 rows by removing a trifoliate from the 6th node from the top of each plant for a total of 12 trifoliates per plot. All whitefly stages falling within a 0.5 cm^2 template placed twice on each side of the midvein of the terminal leaflet of the trifoliate were counted with a stereoscopic microscope giving a total of 4 cm^2 leaf area per trifoliate.

Effects on Immatures. Mean number of whitefly nymphs sampled before treatments commenced were 1.8 (SE = 0.4) and not significantly different among replicates ($F = 0.7$, df = 4, 138, $P > 0.05$). All treatments caused significant reductions in numbers of whiteflies sampled from tomato leaves except for pupae on plants treated with OTC8SE. Significant differences were observed in all stages counted, including eggs. However, differences between treated and untreated were most pronounced in larger instars, reflecting the accumulated effects over instars. There were no significant differences between SE treatments. *Effects on Adults.* Significantly fewer adults were observed from plants treated with SE isolates compared to untreated controls on all 3 sample dates corresponding approximately to 3 generations of whiteflies. The ratio of adults from treated and untreated plots remained relatively constant between 1:2 and 1:3 over a whitefly population increase of more than 20 fold, in spite of likely migration between plots. Again, there were no significant differences in results between SE treatments. adults in the untreated plots were more than 3 fold greater than in treated plots.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1992 - 1995.

Buprofezin (Applaud), a New IGR for Whitefly Control

Applaud®, containing the active ingredient buprofezin, is an insect growth regulator which interferes with the production of chitin, thereby, interrupting the molting process. It is selective in its activity to Hompoteran species such as whiteflies, leafhoppers, planthoppers and scale insects. Applaud is registered in over 70 countries. Applaud is being developed in the U.S. with the intention of receiving a registration on several crops including cotton, citrus, grapes, vegetables, almonds and ornamentals.

Data show that Applaud is very effective against nymphs of the silverleaf whitefly, *Bemisia argentifolii*. Efficacy improved considerably with plot size. Applaud does not have a direct effect on adults. However, indirect effects such as reduced egg lay and reduced hatchability have subsequently shown a reduction of population. Applaud has shown to have essentially no effect on beneficial insects with multiple applications in field situations.

Applaud is an insect growth regulator which has the characteristics of being well suited for Integrated Pest Management and Resistance Management.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 - 1995.

Trends in Resistance to Insecticides in Whitefly Populations from the Yaqui Valley, Sonora, Mexico

The silverleaf whitefly (SLWF) *Bemisia argentifolii* Bellows and Perring, has become since 1991 one of the most important insect pests in northwestern Mexico. In the Yaqui valley of Sonora, this insect has severely damaged soybeans. Due to economics in this crops not more than two insecticide applications were applied to control thrips and lepidopterous and other defoliators. Since 1993 SLWF has become the key main pest, and because not effective control has been achieved by insecticide applications, growers have reduced insecticides and changed to soaps and other control strategies such as planting dates and selection of less susceptible varieties. Cotton another important crop during summer has not have a serious whitefly problem. In order to evaluate changes in susceptibility of SLWF populations to insecticides commonly used in the area, a resistance monitoring program was initiated in 1993. Data obtained are used to evaluate the impact of pest management strategies recommended in the Yaqui valley.

Results from 1993 to 1995 have shown a decrease in the LC_{50} values through time with the organophosphate insecticides methyl parathion and metamidofos. A similar situation has occurred with the cyclodiene endosulfan, but not with a pyrethroid cypermethrin. IN this last case the LC_{50} values have remained about the same since 1993. These trends could be explained by the insecticide change that has taken place in the agricultural system. If not sprays are done in soybeans a dilution of resistance could be expected, since this crops occupies most of the area planted during the summer in the Yaqui valley. SLWF populations have not been a problem up to now for cotton growers that have adjusted their planting dates to recommendations suggested by the experimental station in this valley.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: Spring 1995.

The Effect of "DETUR" on Silverleaf Whitefly (SLWF) Populations in the Imperial Valley of Southern California

The Product "DETUR" (an oil extract from jojoba seeds) demonstrated significant disruption of SLWF populations. Detur (1% solution) was applied to broccoli once per week and twice per week with a high pressure (450 psi) ground rig. A 71% and 98% reduction of SLWF immatures was achieved.

The Effect of "DETUR" on Silverleaf Whitefly (SLWF) Populations on Cantaloupes in the Imperial Valley of Southern California

"DETUR" (an oil extract from jojoba seeds) demonstrated in this test that it provides a "physical barrier" which reduces SLWF feeding and oviposition. Plants were grown free of SLWF and dipped in a 1% solution of DETUR. Plants were placed in a SLWF infested cantaloupe field for one week. The results showed a 78% reduction in SLWF eggs and a 95% reduction in immatures.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1994, through January 1995.

Comparison of Various Formulations of *Beauveria bassiana* with Capture® 2EC Tank Mixed with Orthene® 75S for Control of Silverleaf Whitefly in Cauliflower.

Snow Crown cauliflower seedlings were transplanted into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on September 14, 1994. There were eight insecticide treatments and an untreated control (UTC) in a four replicate randomized complete block design. Insecticide treatments included: Naturalis-L® at 10 fl oz/acre, Naturalis-L® at 15 fl oz/acre, Naturalis-V® at 0.25 lb/acre, Naturalis-V® at 0.5 lb/acre, Naturalis-V® at 1.0 lb/acre, *Beauveria bassiana* (BB 726) at 0.34 lb/acre + Silwet® at 5.12 fl oz/100 gal, Silwet® at 5.12 fl oz/100 gal, and Capture® 2EC at 5.12 fl oz/a + Orthene® 75S at 0.67 lb/a. The foliar sprays were applied 28 September, 3, 17, 21, 24, 31 October, 4, 7, 15 November, and all treatments except Capture® 2EC +Orthene® 75S were applied on 23, 28 November, and 1 December by tractor mounted spray equipment at 80 psi and 14.3 gpa. All Naturalis treatments and Capture 2EC + Orthene 75S included Sylgard® at 4 fl oz/100 gal. All treatments except the untreated control included Helena Buffer® PS at 1 pt/100 gal.

Whitefly adults and immatures were sampled weekly, October 4 through December 7. Adults were sampled from ten plants per plot using a modified Dust Buster™ insect vacuum. Whitefly eggs and nymphs were counted from two disks (1.25 $cm^{2)}$ per leaf from five cauliflower leaves per plot. Yield data were collected December 14 through January 10, as the crop in each plots matured.

There were no significant differences (P=0.05) between the UTC and the various *B. bassiana* formulation treatments nor the silwet treatment for silverleaf whitefly adult mean values for sampling dates 4 October through 7 December, with the exception of Naturalis-V® at 0.25 lb/acre on 30 November. The Capture® 2EC + Orthene® 75S treatment had significantly fewer silverleaf whitefly adults than the UTC on all sampling dates. There were no significant differences among any of the treatments for whitefly eggs on 6 October and 20 October. All treatments except Naturalis-V® at 0.5 lb/acre had fewer whitefly eggs than the UTC on 20 October. With few exceptions there were no significant differences among the *B. bassiana* formulation treatments and the UTC control for eggs mean values from 26 October through 7 December. Capture® 2EC + Orthene® 75S had fewer whitefly eggs than the UTC on all dates from 20 October through 7 December. There were no significant differences among any of the treatments nor the UTC on 6 October. The silverleaf whitefly nymphal mean values for Capture® 2EC + Orthene® 75S were significantly lower than the UTC on all sampling dates from 20 October through 7 December. None of the *B. bassiana* formulations had significantly fewer whitefly nymphs than the UTC on any sampling date with the exceptions of Naturalis-V® at 0.25 lb/acre on 20 October and Naturalis-V® at 0.05 lb/acre on 9 November. Capture® 2EC + Orthene® 75S produced significantly more marketable cauliflower heads than the UTC with harvest starting 19 December. There were no other significant differences among treatments and the UTC for number of markteable heads with harvest delayed for these treatments until 3 January due to whitefly feeding damage. The Naturalis® treatments and BB 726 did not adequately control the silverleaf whitefly in this trial.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March through November, 1995.

Control of Silverleaf Whitefly in Cotton Using Insecticide Rotations

Cotton growers need to preserve the insecticide tool that are currently being used the silverleaf whitefly while economically maintaining lint yield and quality. The purpose of this study was to demonstrate the efficacy of rotation of insecticides in cotton for whitefly control. A stand of cotton, variety DPL 5461, was planted at the University of California Desert Research and Extension Center March 20. Fifty-two plots of 8 beds of 40 inch centers by 45 row-feet were established in a randomized complete experimental design was with 12 insecticide treatments and an untreated control (UTC). Danitol 2.4EC + Orthene 75S was applied without rotation and in rotations with fenoxycarb + CGA-215944, S-71639, Vydate C-LV + Ovasyn 1.5EC, Vydate C-LV + Provado 1.6F, Vydate C-LV + Curacron 8EC, and Vydate C-LV + Bolstar 6EC. Thiodan 3EC + Ovasyn 1.5EC was applied in rotation with Mustang 1.5EW +Orthene 75S and Thiodan 3EC + Curacron 8EC was applied in rotation with Capture 2EC + Vydate C-LV. Capture 2EC + Orthene 75S and Mustang 1.5EC + Thiodan 3EC were applied without rotations with other insecticides. Insecticide treatments were applied weekly from June 19 through August 2, 1995 using a John Deere Hicycle 600 tractor with a rear mounted 4 row spray boom using 7 hollow cone nozzles per row delivering 20 gpa at 80 psi. Whitefly nymphs were counted from two disks (1.25 $cm^{2)}$ per leaf from five cotton leaves per plot sampled from 5 main-stem leaves on randomly selected plants weekly from June 15 through August 9. The whitefly adults were sampled weekly (June 27 throuth August 1) using the leaf turn method, 5 plants selected at random from each plot from the 5th position below the terminal. Yield data as pounds of lint per plot were recorded 7 September.

There were no significant differences (P=0.05) among any of the insecticide treatment nor the UTC means for nymphs on the pre-treatment sampling date of 15 June. The mean number of nymphs for the UTC on 27 June was significantly greater than the means for all treatement rotations with Danitol + Orthene on 19 June. Nymphal means values for all other insecticide treatments applied 19 June, were not significantly different from the UTC on 27 June, 6 days after treatment (DAT). On 4 July, all insecticide treatments except Fenoxycarb + CGA-215944, Mustang + Thiodan, and Capture + Vydate followed by Thiodan + Curacron had nymphal mean values significantly lower than the UTC. The UTC had nymphal mean values significantly lower than all of the insecticide treatments on all sampling dates from 11 July through 9 August. All insecticide treatments maintained fairly low levels of silverleaf whitefly nymphs throughout the sampling period. However, the Mustang + Thiodan treatment had nymphal mean values that were greater than any other insecticide treatment from 18 July through 9 August. Differences among treatment means for the adult whitefly samples were very similar to the differences among nymphal means with respect to the efficacy of the insecticide treatments. The adult mean values for all insecticide treatments remained below the treatment threshold of 10 adults per leaf after 3 July with the following exceptions: Fenoxycarb + CGA-215944 on 3 and 10 July, S-71639 on 10 July, and Mustang + Thiodan on 10, 17, and 24 July. Adult mean values were significantly lower than the UTC for all insecticide treatments on sampling dates from 10 July through 9 August. The mean yield values, as pounds of seed cotton per plot, were significantly greater for all of the insecticide treatments as compared to the UTC. The Danitol + Orthene treatment yield was significantly greater than the Mustang + Thiodan treatment. There were no other significant differences for mean yield values among the insecticide treatments. These results suggest that insecticide rotations could be an economically viable alternatives to the use of Danitol + Orthene without rotation through the cotton growing season.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1994, through January 1995.

Effects of Imidacloprid as Transplant Drench and Soil Treatments on Colonization of Silverleaf Whitefly, Phytotoxicity, Plant Growth, and Marketability of Cauliflower

Snow Crown cauliflower seedlings were transplanted into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on September 14, 1994. There were four insecticide treatments and an untreated control (UTC) in a five by five Latin square design. Imidacloprid treatments as Admire® 2F included: Admire® 2F was applied on September 13, three inches below the transplant line at a rate of 20 fl oz/acre, and flats of cauliflower transplant seedlings were drench treated with Admire® 2F at rates equivalent to 10 fl oz, 15 fl oz, and 20 fl oz/acre.

Whitefly adults and immatures were sampled weekly, September 27 through December 5. Adults were sampled from ten plants per plot using a modified Dust Buster ™ insect vacuum. Whitefly nymphs were counted from two disks (1.25 cm^{2}) per leaf from five cauliflower leaves per plot. Phytotoxicity rating data were collected September 27. Phytotoxicity ratings were 1 through 5, with 1 equal to no damage, ratings of 2-4 equal to increasingly acute leaf margin necrosis, and 5 equal to plant death. Plant growth measurements of height in inches were made on October 31, November 7 and 14. Yield data were collected December 19 through January 8, as the crop in each plots matured.

The adult mean values for the Admire® 2F drench treatments were significantly (P=0.05) lower than the UTC on September 27, but the Admire® 2F soil treatment adult mean value was not significantly different from any other treatment. On October 3, the Admire® 2F soil treatment adult mean value was significantly lower than the UTC and the drench treatments were not significantly different from the UTC nor the soil treatment. The Admire® 2F soil treatment adult mean values were significantly lower than the UTC on all sampling dates from October 10 through December 5 except on November 21 and 28. All Admire® 2F drench treatments had adult mean values significantly lower than the UTC on sampling dates of October 17 through 31, and on December 5. In addition, the adult mean value for Admire® 2F drench treatments at 15 fl oz/acre was significantly lower than the UTC on November 7. The Admire® 2F soil treatment had significantly fewer whitefly eggs than the UTC on all sampling dates from October 3 through November 28 except October 10. all of the Admire® 2F drench treatments had significantly fewer whitefly eggs than the UTC from October 17 through December 5 with the exception of the 15 fl oz/acre rate on December 5. All Admire 2F treatments had fewer whitefly nymphs than the UTC on sampling dates from September 27 through December 5 with the following drench exceptions: 10 fl oz/acre on October 17, November 7 and 21, and December 5, 15 fl oz/acre on November 21, and 20 fl oz/ acre on October 17 and November 7. The phytotoxicity rating means for the Admire® 2F drench treatments ranged from 1.94 to 2.06 and they were significantly greater than the UTC and Admire® 2F soil treatment with 1.24 and 1.16 mean ratings, respectively. The Admire® 2F drench treated plants quickly recovered from the marginal necrosis with normal growth. The mean height of all Admire® 2F treated plants were significantly greater than the UTC on the three sampling dates, but there were no significant differences in plant growth among the drench and soil treatments. There were no significant differences in the numbers of marketable cauliflower heads among the Admire® 2F drench and soil treatments nor the UTC. The UTC had significantly smaller marketable heads resulting in a lower mean value for pounds of cauliflower heads per plot than any of the Admire 2F treatments, but there were no significant differences among the drench or soil treatments.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March 1995 through June 1995.

Efficacy Evaluation of Insecticides for Silverleaf Whitefly Control in Cantaloupe

Cantaloupe, Variety Topmark™, was sown into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on March 8, 1995. There were nine insecticide treatments and an untreated control (UTC) in a four replicate randomized complete block design. Insecticide treatments included: fenoxycarb 40WP at 0.158 lb/a + CGA-215944 (pymetrozine) 50WP at 0.188 lb/a followed by Capture® 2EC at 0.32 pt/a + Phaser® 3EC at 2.67 pt/a, Danitol® 2.4EC at 0.67 pt/a + Orthene® 75S at 0.67 lb/a alternating with S-71639 (pyriproxyfen) 0.83EC at 0.64 pt/a, Danitol® at 0.67 pt/a + Orthene® 75S at 0.67 lb/a, Vydate® L at 0.75 pt/a + Danitol® 2.4EC at 0.67 pt/a, Vydate® L at 0.75 pt/a + Capture® 2EC at 0.32 pt/a, Vydate® L at 0.75 pt/a + Asana® XL at 0.61 pt/a, Capture® 2EC at 0.32 pt/a + Thiodan® 3EC at 2.67 pt/a, and two treatments with Mycotrol® 67WP at 0.25 lb/a and 0.5 lb/a. These foliar sprays were applied weekly (April 27 through May 31) by tractor mounted spray equipment at 80 psi and 23.3 gpa and included Sylgard® at 4 fl oz/100 gal and Helena Buffer® PS at 1 pt/100 gal.

Whitefly nymphs were sampled weekly, April 25 through June 12. Whitefly nymphs were counted from two disks (1.25 $cm^{2)}$ per leaf from five cantaloupe leaves per plot. Adults were sampled from ten plants per plot using a leaf turn method for the 5th leaf from cane terminals, April 25, May 15, 22, and 30, and June 6 and 12. Yield data were collected June 21.

There were no significant (P=0.05) differences among treatment mean values for silverleaf whitefly adults from the pre-treatment sample on April 25. All foliar spray treatments had significantly fewer whitefly adults than the UTC on May 15 and May 22 except Mycotrol® treatments and Vydate® + Asana® on May 22. On May 30, all treatments which included Danitol®, Vydate® + Asana®, and Capture® + Thiodan® had significantly fewer whitefly adults than the UTC. All treatments except Mycotrol® had significantly fewer adults than the UTC on June 6. On June 12, only Danitol® + Orthene® and Capture® + Thiodan® had significantly fewer whitefly adults than the UTC. There were no significant differences among treatment mean values for nymphs from April 27 through May 9, and on May 15 Vydate® + Asana® had significantly more nymphs than the UTC and all other treatments. On May 22, only treatments with Danitol® + Orthene® and Treatments which included Capture® had significantly fewer nymphs than the UTC. Only the treatments which included Danitol® + Orthene® and the Capture® + Thiodan® treatment had significantly fewer nymphs than the UTC on May 30. On June 6, only the Mycotrol® treatments, Vydate® + Danitol®, and Vydate® + Asana® had nymphal mean values that were not significantly lower than the UTC, and on June 12 all treatments except the Mycotrol® treatments had significantly fewer nymphs than the UTC. At harvest all the treatments except the Mycotrol® treatments had significantly greater yields as both number of fruit and pounds of fruit as compared to the UTC. Under the environmental conditions in melon plots at the UC Desert Research and Extension Center during the spring of 1995, Mycotrol® 67WP (*Beauveria bassiana*) did not adequately control silverleaf whitefly.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March through November, 1995.

Efficacy of Various Insecticides Against Silverleaf Whitefly in Cotton

A stand of cotton, variety DPL 5461, was planted at the University of California Desert Research and Extension Center March 24. Plots of 8 beds of 40 inch centers by 45 row-feet were established in a randomized complete experimental design was with 8 insecticide treatments and an untreated control (UTC). Scout® X-TRA was applied at 0.16 pt/a. Combinations with Scout® X-TRA 0.16 pt/a included: Orthene® 90S at 0.56 lb/a, Phaser® 3EC at 2 pt/a, Ovasyn® 1.5EC at 1.33 pt/a, and Lorsban® 4EC at 1.34 pt/a. Other Insecticide treatments were LockOn® 2EC applied at pinhead square at 1.5 pt/a followed by Danitol® 2.4EC at 0.67 pt/a + Orthene® 75S at 0.56 lb/a, LockOn® 2EC at 1.5 pt/a + Ovasyn® 1.5EC at 0.67 pt/a applied at pinhead square followed by Ovasyn® 1.5EC at 1.33 pt/a + Phaser® 3EC at 2 pt/a, and Ovasyn® 1.5EC at 0.67 pt/a + Phaser® 3EC at 1.5 pt/a applied at pinhead square followed by Ovasyn® 1.5EC at 1.33 pt/a + Phaser® 3EC at 1.5 pt/a. Pinhead square treatments were applied on 9 June. In-season insecticide treatments were applied weekly from 19 June through 2 August, 1995 using a John Deere Hicycle 600 tractor with a rear mounted 4 row spray boom using 7 hollow cone nozzles per row. The sprayer delivered twenty gallons per a at 80 psi. Whitefly nymphs were counted from two disks (1.25 $cm^{2)}$ per leaf from five cotton leaves per plot randomly sampled from the 5th main-stem position below the terminal weekly from 26 June through 7 August. Whitefly adults were sampled at pinhead square by 100 sweeps with a standard insect sweep net on 6, 12, and 15 June. The whitefly adults were sampled weekly (3 July through 7 August) using the oil film black pan method, 5 plants randomly selected from each plot and the terminal growth was beaten into the pan twice by hand to dislodge whitefly adults. Yield data as pounds of lint per plot were recorded 6 September. There were no significant differences (P=0.05) among the pinhead square treatment plots and the UTC for whitefly adults on 6 June, the pre-treatment sample. The Ovasyn® + Phaser® treatment had an adult mean value that was significantly lower than the UTC and other pinhead square treatments on 12 June, 3 days after treatment (DAT). The LockOn® + Ovasyn® treatment had significantly fewer whitefly adults than the UTC 3DAT, but was not significantly lower than the LockOn® treatment which was not significantly lower than the UTC for whitefly adults. There were no significant differences among the pinhead square treatments and the UTC for whitefly adults 6DAT. The whitefly adult mean values for the Danitol® + Orthene treatment were significantly lower than all other treatments from 3 July through 7 August except Ovasyn® at 1.33 pt/a + Phaser® at 2 pt/a on 17 July. The adult mean values for Ovasyn® + Phaser® treatments were significantly lower than the UTC and all Scout® X-TRA treatments from 3 July through 7 August with the exceptions of Scout® X-TRA + Phaser® on 10, 17 and 24 July and Scout® X-TRA, Scout® X-TRA + Orthene® and the UTC on 7 August. The adult mean values for all Scout® X-TRA treatments in combination with other insecticides were not significantly lower then the UTC on 3 July, and the Scout® X-TRA treatment alone was significantly greater than the UTC. All of the treatments with Scout® X-TRA included had significantly fewer adults than the UTC on 10 July. Scout® X-TRA in combinations with Orthene®, Phaser®, or Ovasyn® had significantly fewer adults than the UTC on 17 July. Scout® X-TRA + Phaser® had significantly fewer adults than the UTC on 24 and 31 August. There were no significant differences among treatment means for nymphs on 15 June. Danitol® + Orthene® and Ovasyn® + Phaser® treatments had significantly fewer nymphs than the UTC on sampling dates from 26 June through 7 August. Scout® X-TRA + Phaser® had significantly fewer nymphs than the UTC on 10, 17, and 24 July. There were no other insecticide treatments that had significantly fewer nymphs than the UTC. Danitol® + Orthene® had a significantly higher yield of seed cotton than all other treatments. The Ovasyn® + Phaser® treatments and the Scout® X-TRA + Phaser® treatment had the significantly greater seed cotton yields than the UTC and all of the other Scout® X-TRA treatments.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1994, through January 1995.

Insecticide Efficacy Against Silverleaf Whitefly in Broccoli

Broccoli variety Ninja was planted into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on September 12, 1994. There were seven insecticide treatments and an untreated control (UTC) in a four replicate randomized complete block design. Insecticide treatments included: Scout® X-TRA applied at rates of 2.33 fl oz, 2.56 fl oz, 2.90 fl oz and 3.33 fl oz/acre, Asana® 0.66 EC applied at 9.60 fl oz/acre, Danitol® 2.4 EC + Orthene® 75S applied at 10.67 fl oz and 1.0 lb/acre, respectively, and Capture® 2EC + Lannate® LV applied at 5.12 fl oz and 2.5 pt/acre, respectively. The sprays were applied weekly (September 29 through November 16) by tractor mounted spray equipment at 80 psi and 14.3 gpa and included Sylgard® at 4 fl oz/100 gal and Helena Buffer® PS at 1 pt/100 gal.

Whitefly adults and nymphs were sampled weekly, October 4 through November 22. Adults were sampled from ten plants per plot using a modified Dust Buster™ insect vacuum. Whitefly nymphs were counted from two disks (1.25 cm^2) per leaf from five cauliflower leaves per plot. Yield data as number of marketable broccoli heads and pounds of broccoli per plot were collected January 10 through January 27, as the crop in each plots matured.

On October 4, the UTC, Capture® 2EC + Lannate® LV, and Danitol® 2.4 EC + Orthene® 75S had significantly (P=0.05) lower numbers of adult silverleaf whitefly than Asana 0.66 EC and all of the Scout® X-TRA treatments. On sampling dates from October 11 through November 22, the Capture® 2EC + Lannate® LV and Danitol® 2.4 EC + Orthene 75S treatments had significantly fewer adult whitefly than all other treatments with the exception of Asana® 0.66 EC on November 8. Silverleaf whitefly adult mean values for the UTC were not significantly different from the mean values for Asana® 0.66 EC and the Scout® X-TRA treatments on sampling dates from October 11 through November 22 with the exception of Asana® 0.66 EC on November 22. Capture® 2EC + Lannate® LV had significantly more whitefly nymphs than the UTC, Scout® X-TRA at 2.56 fl oz/acre, and Scout® X-TRA at 2.90 fl oz/acre on October 5, but there were no other significant differences among treatments on that sampling date. Capture® 2EC + Lannate® LV and Danitol® 2.4 EC + Orthene® 75S had mean values for whitefly nymphs that were significantly lower than the UTC, Asana 0.66 EC, and the Scout® X-TRA treatments on sampling dates from October 11 through November 22, with the exception of Capture® 2EC + Lannate® LV on October 11. Danitol® 2.4 EC + Orthene® 75S had significantly fewer whitefly nymphs than Capture® 2EC + Lannate® LV on the sampling dates of October 25 and November 8. Scout® X-TRA treatments and Asana® 0.66 EC treatment mean values for whitefly nymphs were not significantly lower than the UTC on any sampling dates except on October 25 when all but the Scout® X-TRA 2.56 fl oz/acre rate were significantly lower than the UTC and on November 15 the Scout® X-TRA 3.33 fl oz/acre rate was significantly lower than the UTC. There were no significant differences among treatments for number of marketable broccoli heads, but the harvest for Capture® 2EC + Lannate® LV and for Danitol® 2.4 EC + Orthene® 75S were started a week earlier than any other treatments as the crop matured more quickly in these plots. Danitol® 2.4 EC + Orthene® 75S had a significantly higher yields as pounds of broccoli per plot than all treatments except Capture® 2EC + Lannate® LV which had a significantly higher mean yield value than the Scout® X-TRA treatments and the UTC. Asana® 0.66 EC had a significantly higher mean yield value than the UTC, but was not significantly different from the Scout® X-TRA treatments nor the Capture® 2EC + Lannate® LV treatment.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: September 1994, through January 1995.

Insecticide Efficacy Against Silverleaf Whitefly in Cauliflower

Snow Crown cauliflower seedlings were transplanted into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on September 14, 1994. There were nine insecticide treatments and an untreated control in a four replicate randomized complete block design. Insecticide treatments included: Admire® 2F applied on September 13, three inches below the transplant line at rates of 8 fl oz/a, 16 fl oz/a, and 32 fl oz/a. One 8 fl oz/a Admire® treatment was followed by Asana® 0.66 EC at 9.6 fl oz/a + Lannate® LV at 2.5 pt/a as a foliar spray. Another 8 fl oz/a Admire® treatment was followed by Thiodan® 3EC at 1.33 pt/a foliar treatment. The foliar sprays were applied weekly, October 20 through November 16. Other foliar treatments included Phaser® 3EC applied at 1.33 pt/a, 2.0 pt/a, and 2.33 pt/a, Capture® 2EC at 5.12 fl oz/a + Thiodan® 3EC at 1.33 pt/a, and Capture® 2EC at 5.12 fl oz/a + Orthene® 75S at 0.67 lb/a. These foliar sprays were applied weekly (September 28 through November 16) by tractor mounted spray equipment at 80 psi and 14.3 gpa and included Sylgard® at 4 fl oz/100 gal and Helena Buffer® PS at 1 pt/100 gal.

Whitefly adults and immatures were sampled weekly, October 4 through November 29. Adults were sampled from ten plants per plot using a modified Dust Buster™ insect vacuum. Whitefly nymphs were counted from two disks (1.25 $cm^{2)}$ per leaf from five cauliflower leaves per plot. Yield data were collected December 14 through January 10, as the crop in each plots matured.

The untreated control had more silverleaf whitefly adults and nymphs than any of the insecticide treatments with seasonal means of 36.1 and 40.9, respectively. The Phaser® treatments had seasonal means for adult whitefly ranging from 21.4 to 25.4 as compared to the treatments with Capture® 2EC which ranged from 14.4 to 17.3 and treatments with Admire® which ranged from 10.3 to 12.0 for adult seasonal means. The seasonal means for silverleaf whitefly nymphs were similar to the results for adults with Phaser® treatments means ranging from 26.9 to 31.6 nymphs per cm^2 and the other insecticide treatments ranging from 4.7 to 15.3 nymphs per cm^2. Similarly the yield data followed the same pattern with the untreated control and the Phaser® treatments producing fewer marketable cauliflower heads and the harvest initiation was delayed by one to two weeks. The other insecticide treatments were similar as a group with harvest starting on the same date and with the number of marketable cauliflower heads and the weight of the heads being similar.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: March 1995 through June 1995.

Insecticide Efficacy Against Silverleaf Whitefly in Tomato

Shady Lady tomato seedlings were transplanted into plots for an insecticide efficacy trial at the University of California Desert Research and Extension Center on March 13, 1994. There were 13 insecticide treatments and an untreated control (UTC) in a 4 replicate randomized complete block design. Four Admire® 2F treatments were applied on March 9, three inches below the transplant line at rates of 16 fl oz/ac and 24 fl oz/ac. One 16 fl oz/a Admire® treatment was followed by pyriproxyfen (S-71639) at 0.636 fl oz/ac as a foliar spray. A second 16 fl oz/a Admire® treatment was followed by Baythroid® 2EC at 0.125 pt/a foliar treatment. A third 16 fl oz/a Admire® treatment was followed by a foliar treatment of Monitor® 4 at 1.5 pt/a. A fourth Admire® 2F treatment at 20 fl oz/ac was not followed by foliar sprays. Other foliar treatments included Phaser® 3EC applied at 1.33 pt/a, 2.0 pt/a, and 2.67 pt/a, fenoxycarb 40WP applied at 0.158 lb/a + CGA-215944 50WP at 0.188 lb/a followed by Asana® XL applied at 0.6 pt/a + Monitor® 4 at 1.5 pt/a, Asana® XL at 0.6 pt/a + Monitor® 4 at 1.5 pt/a, Danitol® 2.4EC at 0.672 pt/a + Monitor® 4 at 1.5 pt/a, Vydate® L at 3 pt/a + Danitol® 2.4EC at 0.67 pt/a, Vydate® L at 3 pt/a + Thiodan 3EC at 2.66 pt/a, and S-71639 0.83EC at 0.64 pt/a. These foliar sprays were applied weekly (May 1 through June 5) by tractor mounted spray equipment at 80 psi and 14.3 gpa and included Sylgard® at 4 fl oz/100 gal and Helena Buffer® PS at 1 pt/100 gal. Whitefly immatures were sampled weekly, April 27 through June 8. Whitefly nymphs were counted from four disks (1.25 $cm^{2)}$ per leaf from five tomato leaves per plot. Adults were sampled from ten plants per plot using a modified Dust Buster™ insect vacuum on May 16, 24, and 31. Yield and percent irregular ripening data were collected June 13.

There were no significant (P=0.05) differences among the silverleaf whitefly adult mean values on May 16. Only the Danitol® + Monitor® treatment had significantly fewer whitefly adults than the UTC on May 24. On May 31 all of the Admire® 2F treatments, S-71639, and Vydate® + Thiodan® had whitefly adult mean values that were not significantly different from the UTC on May 31. The adult mean values for all of the Phaser treatments were significantly less than the UTC. Danitol® + Monitor® had a mean value for whitefly adults that was significantly lower than all treatments except Asana® + Monitor® and Vydate® + Danitol® on May 31. There were no significant differences for nymphal mean values among any of the treatments on April 27, prior to the initiation of foliar sprays. Only the Admire® treatments had significantly fewer nymphs than the UTC on May 3. On May 10, the 24 fl oz/a rate of Admire® had significantly were nymphs than the S-71639 treatment and the Vydate® + Thiodan® treatment, but there were no other significant differences among treatments. Admire® at 24 fl oz/a and Admire® at 16 fl oz/a followed by Monitor® sprays had significantly fewer nymphs than the UTC on May 16. On May 24, all Admire® treatments, S-71639, and Danitol® + Monitor® had significantly fewer nymphs than the UTC. Only Danitol® + Monitor®, S-71639, and Admire® followed by S-71639 had significantly fewer nymphs than the UTC, and on June 8 only Danitol® + Monitor®, Asana® + Monitor®, and S-71639 had nymphal mean values lower than the UTC.

There were no significant differences among the treatments for either the number of marketable fruit or the pounds of marketable fruit. Treatments with significantly lower percentages of fruit with irregular ripening than the UTC (93%) included Danitol® + Monitor® (30%), Admire® followed by S-71639 (35%), Asana® + Monitor® (55%), S-71639 (58%), Admire® at 24 fl oz/a (65%), Phaser at 2 pt/a (65%), and Vydate® + Thiodan® (68%). The percent irregular ripening was high even among the treatments with the best whitefly control. Nymph counts were low over all treatments with the UTC ranging from 0.13- 12.2/cm^2 of leaf.

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Research & Implementation Area: Section C: Chemical Control, Biorationals and Pesticide Application Technology

Dates Covered by the Report: 1994-1995.

Imidacloprid Field Performance on Commercial Lettuce in Arizona

Imidacloprid (Admire 2F), a new insecticide, has recently been developed for control of sucking insect pests. The compound has been available for commercial use in Arizona since 1993. Studies were conducted during the fall of 1993, 1994 and 1995 to investigate the field performance of imidacloprid for controlling silverleaf whiteflies, *Bemisia argentifolii* Bellows and Perring (also known as b-strain sweetpotato whitefly, *Bemisia tabaci* Genn.), in commercial lettuce fields in Yuma, Arizona. Field trials were established each year by replicating paired imidacloprid treated and untreated plots three times in fields in the Yuma, Gila and Dome Valleys. Field performance evaluations were conducted in seven fields in 1993 and six fields in 1994 and 1995. Assessments of whitefly densities were made at the thinning, heading and harvest stages by sampling 10-20 leaves per plot and recording the total number of eggs, nymphs and eclosed pupal cases on 4-cm^2 leaf discs/leaf. Yield assessments were made by recording the total number of heads per 10 m/plot, head weight and diameter, and incidence of chlorosis. Relative leaf chlorophyll levels was measured using a nondestructive chlorophyll meter.

Populations of whiteflies in the respective experimental sites were high in 1993 and 1994, with migratory adult populations active from plant emergence through the heading stage. Adult numbers generally declined from heading to harvest relative to cotton plowdown in adjacent fields and cooler temperatures. Untreated plots contained significantly greater numbers of whitefly eggs and nymphs than did imidacloprid plots throughout the season in both experimental and commercial tests. Colonization was significantly reduced ($P<0.05$) in imidacloprid plots as indicated by low incidence of eclosed pupal cases. At the thinning and heading stages, Relative Growth Rates ($mg \cdot mg^{-1} \cdot d^{-1}$) of plants treated with imidacloprid were greater than untreated plants. At harvest, a significant yield response was observed in plots treated with imidacloprid. Head wt and diam were considered commercially acceptable with most heads (>80%) marketable in the imidacloprid plots. However, plants in the untreated plots were chlorotic, and head weight and size were significantly reduced. Marketability of untreated lettuce never exceeded 20%. Measurement of chlorophyll levels in 1994 showed that leaf chlorosis in untreated plots was significantly greater than in lettuce treated with imidacloprid. Populations of whiteflies at the experimental sites in 1995 were low as the period of migration occurring for only a short period in September. As a result, differences in whitefly densities and yield responses between the untreated and imidacloprid-treated plots were not significant at most sites. Overall, the control of silverleaf whitefly provided by imidacloprid and the associated yield and quality response of lettuce was consistent throughout the Yuma growing region during the past 3 years of use. At the present time there appears to be no indication of tolerance to imidacloprid by whiteflies.

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Research & Implementation Area: Section C: Chemical Control, Biorationals and Pesticide Application Technology

Dates Covered by the Report: 1994 - 1995.

Imidacloprid Formulation and Soil Placement: Effects on Colonization by Sweetpotato Whitefly on Head Size and Incidence of Chlorosis in Lettuce

The effects of imidacloprid formulation and soil placement on colonization by sweetpotato whitefly, *Bemisia tabaci* (Gennadius), at three plant growth stages of lettuce, *Lactuca sativa* L., were evaluated in experimental and commercial lettuce plots in 1993-1994. We also evaluated the effects of imidacloprid treatments on yield response and incidence of chlorosis associated with whitefly control. Imidacloprid placement had a significant affect on whitefly colonization in lettuce throughout the experimental period. Whitefly densities on lettuce varied at each plant stage relative to depth of placement within the lettuce seed bed. Applications made to the soil surface and at 4.0 cm sub-seed furrow followed by irrigation, provided the most consistent control of whitefly nymphs in both small plot and on-farm lettuce plots. These imidacloprid soil treatments also prevented reductions in head size and incidence of leaf chlorosis associated with whitefly colonization in lettuce. Our data suggest that incorporation of imidacloprid into the upper 3-4 cm of soil below the seed furrow is optimal for absorption and translocation by lettuce roots. Imidacloprid soil treatments may provide a more environmentally suitable and effective alternative to control of whiteflies in lettuce than is currently possible with foliar insecticide treatments.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Effect of Synergists on Pyrethroid and Organophosphate Resistance in *Bemisia tabaci*

A field strain of *Bemisia tabaci* (Gennadius) from Imperial Valley, CA was selected with bifenthrin and chlorpyrifos for 25 generations under greenhouse conditions. Resistance increased rapidly under selection to bifenthrin (RR=109) and moderately to chlorpyrifos (RR=30). Selective synergists were used to study the involvement of hydrolytic or oxidative enzymes (or both) in the resistance mechanisms of these two strains. Resistance levels were decreased when DEF (S,S,S-tributyl phosphorotrithioate) synergised chlorpyrifos and to a more limited extent bifenthrin, suggesting the involvement of increased detoxication by esterases as part of the resistance mechanism. Piperonyl butoxide (PB) synergised both bifenthrin and chlorpyrifos to different degrees in both susceptible and resistant strains, thus indicating the importance of oxidative metabolism in whitefly resistance. Because use of the synergists DEF and PB did not increase the toxicity in the resistant strains to that of the susceptible strain, an unidentified resistance factor, possibly insensitive acetylcholinesterase, may be of importance in OP resistance. A nonmetabolic knockdown resistance mechanism (*kdr*) may be a factor in bifenthrin resistance because neither DEF nor PB suppressed resistance completely.

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Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1994 - 1995.

Evaluation of Insecticide Rotations and Mixtures as a Resistance Management Strategy for Whiteflies

Among the cotton growing states in US, California and Arizona have been affected the most by intense and consistent infestations of *Bemisia tabaci*. Because of the temporal sequence and overlapping of crops, successive generations of whiteflies are exposed to insecticides on a continuous basis. Heavy reliance upon insecticides for reducing infestations in cotton and other crops heightens concern about the development of insecticide resistance in whitefly populations. To evaluate potential antiresistance strategies for whitefly populations, two principle approaches, insecticide rotations and insecticide mixtures, have been studied in both greenhouse and field settings. High levels of resistance (101-fold) to bifenthrin were recorded for whiteflies in greenhouse colonies subjected to continuous bifenthrin exposure. Resistance increased to moderate levels (27- to 31-fold) to endosulfan and chlorpyrifos under continuous selection pressure. However, only low levels of resistance (5- to 10-fold) were observed in colonies exposed to similar insecticide pressure, but in a rotational scheme using the same three insecticides. Similar contrasts in resistance levels were observed favoring mixtures of two insecticides over single compounds.

Field trials were conducted in 1994 at two sites in the Imperial Valley, CA, and in 1995 at sites in Imperial Valley and Yuma, AZ, to evaluate insecticide rotations and mixtures as resistance management strategies for whiteflies. Insecticide treatment regimens included continuous treatment plots with single insecticides using bifenthrin, endosulfan, chlorpyrifos and amitraz, rotation plots with the same four insecticides, a mixture treatment with bifenthrin and endosulfan, and untreated control plots. Ten consecutive weeks of bioassay results with the yellow sticky card technique failed to yield discernible differences in the insecticide treatment regimens (continuous, rotation, or untreated). However, there appeared to be a general trend of decreasing $LC_{50's}$ through time in most of the treatment plots. Significant differences among the various treatment plots were observed in the densities of preimaginal whiteflies infesting the plots and in the yield of cotton from the respective plots. The continuous treatment of bifenthrin and the bifenthrin + endosulfan mixture had significantly fewer whiteflies during mid- and late experiment compared to the other treatment plots at both locations, and highest yields of cotton were also obtained in these plots. Although whitefly densities in the rotation plots were marginally higher than the bifenthrin or bifenthrin + endosulfan plots, the rotation regimen produced significantly lower whitefly densities and higher cotton yield than the control plots or the single treatment plots of endosulfan, chlorpyrifos or amitraz.

Investigator's Name(s): A.L. Simmons and T.J. Dennehy.

Affiliation & Location: University of Arizona, Department of Entomology, Extension Arthropod Resistance Management Laboratory, Tucson, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Contrasts of Three Insecticide Resistance Monitoring Methods for Whitefly

Three resistance monitoring methods were tested to evaluate their relative reliability, discriminating ability, convenience, and practicality for monitoring insecticide resistance in Arizona whiteflies. Adult whiteflies were collected from the field and tested in the laboratory with three methods: leaf disk, sticky trap, and vial. Each method was evaluated using a mixture of Danitol® + Orthene® and two single chemicals, Thiodan® and Danitol®, against two populations divergent in susceptibility. The Yuma population was relatively susceptible and the Gila River Basin population highly resistant. Correlations of field efficacy and leaf disk bioassays were conducted with the Yuma population and a comparatively resistant Maricopa population. At each location egg, immature, and adult whitefly densities were monitored before and after Danitol® + Orthene® treatments and resistance estimates were also monitored in the populations using leaf disk bioassays.

Our results illustrated that the leaf disk method had the greatest discriminating ability between susceptible and resistant populations. The results also indicated that the vial method was the most practical, and that the sticky trap method was good at discriminating between populations which have large differences in susceptibility. The field efficacy trials indicated results from leaf disk assays reflected what had occurred in the field.

Investigator's Name(s): S. Sivasupramaniam, S. Johnson, T.F. Watson, A.A. Osman, and R. Jassim.

Affiliation & Location: Department of Entomology, University of Arizona, Tucson, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1992 to 1995 Field Seasons.

A four-year study on monitoring resistance of the silverleaf whitefly to organophosphorus+pyrethroid, cyclodiene, and pyrethroid insecticides in Arizona

Baseline data on tolerance of the silverleaf whitefly (SLWF) populations to bifenthrin, endosulfan, fenpropathrin, and fenpropathrin+acephate was documented in 1992 and 1993. The treated glass vial technique was successfully used to monitor tolerance to these insecticides in field populations of adult SLWF on different host crops in Phoenix and Yuma, Arizona. Based on these results, three discriminatory doses for each test chemical were selected for use in the 1994 and 1995 monitoring studies. Resistance gene frequencies to pyrethroids, and the pyrethroid+oraganophosphorus combination were highest in the Phoenix populations in 1995. The test provided valuable information needed to design more efficient resistance management strategies to combat the silverleaf whitefly.

Investigator's Name(s): S. Sivasupramaniam and T.F. Watson.

Affiliation & Location: Department of Entomology, University of Arizona, Tucson, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1993 to 1995 Field Seasons.

Selection for Fenpropathrin and Fenpropathrin+Acephate Resistance in the Silverleaf Whitefly (Homoptera: Aleyrodidae) and Reversion of Fenpropathrin+Acephate Resistance

A large, genetically diverse pool of silverleaf whitefles (SPWF), *Bemisia argentifolii* Bellows and Perring, was collected in 1994 from different crops, and a mixed colony established in our laboratory. Subsets of this colony were reared on cotton plants held in large Perspex cages and adult whiteflies were selected for resistance to fenpropathrin and to fenpropathrin+acephate (1:5). Selection was performed by exposing adults to treated glass vials at doses sufficient to give 60-80% mortality. Thirteen generations of adult selection with fenpropathrin + acephate yielded 762.8- and 1173.5-fold tolerance, respectively, to fenpropathrin and to fenpropathrin+acephate. In contrast, selection with fenpropathrin alone yielded only a 11.8-fold increase in tolerance to fenpropathrin at the end of the selection period. There was no significant change in tolerance to fenpropathrin+acephate in this strain. Fenpropathrin+acephate evidently possesses a high degree of selectivity for development of resistance in SPWF. Rearing of the fenpropathrin+acephate-resistant strain under conditions free of insecticides for six generations, did not result in any significant decline in resistance, indicating that resistance is fairly stable. Mixing of the sucseptible check strain with the fenpropathrin + acephate-selected strain in a 1:1 and 1:3 ratio resulted in a drop in fenpropathrin+acephate tolerance in the mixed stains after two generations.

Investigator's Name(s): Livy Williams III[1], Timothy J. Dennehy[1], and John C. Palumbo[2].

Affiliation & Location: [1]University of Arizona, Department of Entomology, Extension Arthropod Resistance Management Laboratory, Tucson, AZ; [2]University of Arizona, Department of Entomology, Yuma Valley Agricultural Center, Yuma, AZ.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995.

Whitefly Control in Arizona: Development of a Resistance Management Program for Imidacloprid

In 1995 we initiated a resistance management program aimed at sustaining the efficacy of imidacloprid. This paper delineates the groundwork for the program, and describes methodological and conceptual advances toward our goal. Bioassay methods developed for adult whitefly consisted of a 1 day hydroponic uptake procedure using cotton seedlings. A reliable mortality criterion was also established. Results from a statewide survey suggested slight geographic variation in whitefly susceptibility to imidacloprid. Long-term studies will 1) evaluate the risk of resistance to whitefly populations in commercial greenhouses, and relate this to field populations, and 2) characterize the development of resistance in relation to cropping systems and spatial dynamics of whitefly. The overall objective of these investigations is to determine if a sustainable use strategy can be identified for imidacloprid.

Investigator's Name(s): Dan A. Wolfenbarger.

Affiliation & Location: USDA-ARS, Crop Insects Research Unit, Weslaco, TX.

Research & Implementation Area: Section C: Chemical Control, Biorationals, and Pesticide Application Technology.

Dates Covered by the Report: 1995 Season (March - August).

Insecticides in Laminated Plastic

Plastic on stakes containing bifenthrin and dichlorvos, at 1000/HA, was not effective in cotton fields in reducing season-long adult populations of silverleaf whitefly or increasing yields of cotton compared to untreated check. Yields of cotton treated with season-long sprays of fenpropathion and acephate were greater than plastic with insecticides on stakes above cotton or untreated check.

Glass vial bioassays of bifenthrin and endosulfan show no resistance during the growing season. No resistance was shown the two previous years.

TABLE C. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved		Significance
		Yes	No	
C.1 Identify for registration, new chemicals and formulations that effectively control SPW.	Yr. 4: Determine chemical effects of SPW populations, increased yields, and quality of crops to provide data useful for registration purposes.			
C.2 Identify for registration, biorational materials with new modes of action.	Yr. 4: Develop alternating sequences between chemicals and biorationals for best SPW management system.			
C.3 Develop application schedules and methods in relation to economic thresholds.	Yr. 4: Validate estimated economic threshold concept and insecticide use patterns.			
C.4 Insecticide resistance studies.	Yr. 4: Initiate study to determine mode of action of insecticides.			
C.5 Genetics of insecticide resistance in SPW.	Yr. 4: Isolate individual resistance genes in back-crossed lines and determine cross-resistance relationships.			
C.6 Develop methods for application or delivery of materials to improve control.	Yr. 4: Verify best of the current state-of-the-art application equipment.			
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Yr. 4: Determine optimum and best materials and application technology to develop maximum natural enemy conservation.			

SECTION D: BIOLOGICAL CONTROL

Co-Chairs: Kevin Heinz and Oscar Minkenberg

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): J.B. Carlton, I.W. Kirk, and M.A. Latheef.

Affiliation & Location: USDA-ARS, Areawide Pest Management Research Unit, College Station, Texas.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1, 1995 - September 30, 1995.

Aerial Electrostatic Charged Sprays for Control of Sweetpotato Whitefly in Cotton

A season-long aerial electrostatic spray charging program was undertaken to determine the feasibility of controlling whitefly in cotton. Sixty acres of whitefly infested production cotton was made available for the study by the University of Arizona, Maricopa Agricultural Center, Maricopa, AZ. In the insecticide s pray treatments formed, we sought to compare three spray charging techniques with that of conventional aerial spraying for whitefly. The season-long control effort consisted of six aerial pesticide applications over the test plots. The large-scale experimental study resulted in many detailed conclusions. From an overall season perspective, one of the three aerial electrostatic spray charging protocols (0.5 gal/acre) gave cotton deposition levels of active ingredient that were equal to or significantly higher than that of the conventional protocol. The latter used CP nozzles and applied the same active ingredients but at 5 gal/acre.

Investigator's Name(s): Ray Carruthers[2], Matthew Ciomperlik[1], Ken Esau[1], John Goolsby[1], Clifford Bradley[4], Walker Jones[2], Benjamin Legaspi[3], Paul Parker[1], Tad Poprawski[3], Merrit Taylor[3], Don Vacek[1], Lloyd Wendel[1], and Steve Wraight[2].

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center[1], USDA-ARS-SARL,Weslaco, TX[2], Texas Agricultural Experiment Station, Weslaco, TX[3], and Mycotech Corporation, Butte, MT[4].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: Fall 1995.

Demonstration of Biological Control Based IPM of Sweetpotato Whitefly

Demonstration and evaluation of biological control of *Bemisia tabaci* (Biotype B) (SPWF), on a year round rotation of broccoli, fall cucumbers, cantaloupe melons, and cotton, using parasitoids, predators, and pathogens is in progress. The evaluation program will take place on a 20 acre irrigated farm located at USDA-APHIS-PPQ, Mission Biological Control Center (MBCC) on Moore Airbase, Mission, TX. Fall, winter, spring, and summer crops will be grown in 5 acre plots in a seasonal rotation. Conventional farming practices typical to the Lower Rio Grande Valley (LRGV) will be used to insure proper fertility and weed control in each of the crops. The critical difference between the 20 acre demonstration farm and conventional agriculture being biological control based integrated pest management (BC-IPM) will be used to control arthropod pests. Three species of parasitoids and a fungal pathogen will be released augmentatively throughout the season to manage field populations of SPWF. Refuge strips interspersed in the crops will be used to conserve and enhance the numbers of established parasitoids and predators. To determine the success or shortcomings of a BC-IPM program, the economics and marketability of each crop will be evaluated.

Three exotic parasitoid species *Encarsia* nr. *pergandiella* (M94055 Sete Lagoas, Brazil), *Eretmocerus* sp. (M95012 Multan, Pakistan), and *Eretmocerus* sp. (M92014 Murcia, Spain) were chosen for this demonstration based on laboratory and field evaluations conducted at MBCC during 94-95. The deuteromycete fungus *Beauveria bassiana* was selected for application based on its commercial availability and demonstrated efficacy against preimaginal whiteflies. A wettable powder formulation of conidiospores of this pathogen tradenamed Mycotrol-WP[5] was codeveloped by Mycotech Corporation of Butte, Montana and the USDA-ARS Subtropical Agricultural Research Laboratory (SARL) in Weslaco, Texas and was recently granted EPA registration. In the initial test season (Fall 1995), studies were conducted in two fields of drip-irrigated cucumbers located approximately one mile apart. Both parasite releases and fungus applications were made in one field while the other received only fungus treatments. Each species of exotic parasitoid was released weekly a the rate of 17,000 adults per acre or approximately one per plant. A total of five fungus applications were made at 7-day intervals at an average rate of 1.5×10^{13} conidia per acre using an experimental high-pressure hydraulic sprayer (400 psi) with nozzles spaced eight inches apart and carried 4-5 inches above the ground. Leaf samples were collected on six occasions between 5 October and 8 November (prior to harvest). Samples to monitor parasitoid establishment are continuing.

Preliminary analysis of the data indicate that the *Beauveria* spray applications reduced populations of whitefly nymphs by 60-70% within three to four weeks after initiation of the spray program; numbers of late instar nymphs were reduced by 70-75%. Rates of parasitism remained low (<5%) throughout the preharvest period across both fields, including areas not sprayed with fungus. Plans are underway to continue these studies during the 1996 season.

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[5] Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

Investigator's Name(s): Albino Chavarria[1], John A. Goolsby[1], & Lloyd E. Wendel[1].

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center[1].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Field Cage Rearing of Exotic Parasitoids

Field cage insectary production of SPWF and its natural enemies is a reliable, year-round method of mass rearing individuals for field release programs. The advantages of field cage production are: 1) lower cost of production; 2) higher production; and 3) a more robust field reared parasitoid. Selected species of parasitoids are produced in (10 X 10 ft.) field cages containing 154 pots of eggplant. Each cage is infested with 20,000 SPWF adults which are held 3 days for oviposition. When the SPWF nymphs reach 2nd instar up to 10,000 adult parasitoids are released over a 3 day period. The mature parasite pupae are harvested by clipping the leaves which can be shipped to cooperators or held for emergence of adults.

Current methods of field insectary production produce approximately 110,000 parasite immatures per cage with a new cage ready for harvest each week. Production parameters of two of the *Eretmocerus* sp. (M92014 Spain) and (M92019 India) were compared for the months of Feb. through July of 1995. The mean fecundity per female was not significantly different at 15.3 and 11.9 for M92014 and M92019 respectively. Similarly, there was no significant difference the mean number of immatures reared per cage at 138,121 and 114,021 for M92014 and M92019 respectively.

Investigator's Name(s): Matthew A. Ciomperlik, Juan M. Rodriguez, Lloyd E. Wendel.

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center, Mission, TX.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: Oct. 1994 - Oct. 1995.

Assessments of Sweetpotato Whitefly (*Bemisia tabaci*, biotype B) and Indigenous Parasite Populations in Agroecosystems of the Lower Rio Grande Valley, TX.

During 1994 and 1995, USDA-APHIS-PPQ, Mission Biological Control Center and APHIS-PPQ, Central Region personnel surveyed 28 field sites for Sweetpotato Whitefly (SPWF) and indigenous natural enemies. The field sites were located along four major highways that transect the four counties that comprise the Lower Rio Grande Valley (LRGV). Data collected in the field included: crop type and growth stage, adult whitefly per leaf via vacuum sampling, and weather conditions. Leaf samples of crops and weedy plant species that supported immature whitefly were collected from the field and returned to the laboratory. Counts of whitefly nymphs and parasitized nymphs were made in the laboratory. Parasitized nymphs were held for emergence and adult parasites were identified and separated according to species, sorted to gender, and counted. Several trends in SPWF and parasite populations are discernible from this data.

Low to moderate SPWF population densities were observed in winter vegetables like cabbage, broccoli, and Swiss chard. SPWF populations moved from winter vegetables to spring melons and cucurbits, reaching damaging population levels in both crops. SPWF populations migrated from these crops to cotton, where they continued to increase. The SPWF population reached peak numbers in the summer months of June and July. Defoliation of cotton in August forced a migration of SPWF to fall vegetables that include melons, cucurbits, and crucifers. Six weed species were also found to harbor low to moderate SPWF densities. Of these weeds, Sowthistle (*Sonchus oleraceae*) and Redroot pigweed (*Amaranthus retroflexus*) supported the greatest SPWF populations. These two weeds are very prevalent in the LRGV, most often in row crops, crop turn-rows, and arable fields.

Six parasite species of SPWF were collected and identified from the crop and weedy plant samples. The seven parasite species, in order of greatest abundance to least, were: *Eretmocerus* sp. nov., *Encarsia pergandiella*, *Encarsia meritoria*, *Encarsia* sp. nr. *strenua*, *Encarsia luteola*, and *Encarsia formosa*. *Er.* sp. nr. *californicus* and *En. pergandiella* occurred in about 95% of all the samples, and both appear to have a cosmopolitan distribution throughout the LRGV. Population trends of the two most abundant parasite species were similar to that of SPWF. Parasite populations were low in winter months in crucifer crops, increased in spring melons and cucurbits, and reached peak numbers in summer months in cotton. Parasite populations declined slightly during the fall in cucurbits and melons.

Overall abundance of parasite populations in 1995 were substantially less than those sampled in 1994. Reasons behind the observed decline in parasite abundance in 1995 are most likely attributable to severe drought conditions that occurred during this period in the LRGV. However, increased insecticide inputs as a result of the Bollweevil eradication program cannot be discounted.

Investigator's Name(s): Matthew A. Ciomperlik[1] and John A. Goolsby[1].

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center[1].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: Oct. 1994 - Sept. 1995.

Field Impact Evaluations of Exotic Parasitoids in the Lower Rio Grande Valley on Selected Crops

Candidate natural enemies that showed promise in laboratory evaluations were further evaluated for their potential to parasitize SPWF under field conditions . Leaves of the subject crop were visually inspected for the presence of approximately 500-750 SPWF eggs. Once the leaves were determined to be suitable for use, a sleeve cage was placed over the leaf. When the SPWF immatures reached mixed populations of second and third instars, female *Eretmocerus* parasites were introduced into the sleeve cage. *Encarsia* parasites were released when the SPWF immatures reached third to fourth instar. Two single females < 24 hours old were introduced into each sleeve cage. Twenty replicates were set up per parasite species/population and an additional twenty replicates served as controls. The female parasites were allowed to oviposit for a period of 15 days, at which point in time the experiment was terminated. Each sleeved leaf was cut from the plant and counts of SPWF exuviae, and parasitoid immatures were conducted.

In kale, *Eretmocerus* sp. (M92014 Spain and M92019 India) and *Encarsia* spp. (*E. lutea*, M94107 Israel, *E. pergandiella*, M94055 Brazil, and *E. transvena*, M93003 Spain) were evaluated.. In melons, *Eretmocerus* spp. (M92014 Spain, M92019 India, M94120 Israel, M94023 Thailand) and *Encarsia* spp., (*E. pergandiella*, M94055 Brazil; *E. lutea*, M93064 Cyprus; *Encarsia* sp. nov., M92018 India; and *E. transvena,* M93003 Spain) were tested. In cotton, *Eretmocerus* spp. (M95012 Pakistan, M92019 India, M92014 Spain, M94036 Thailand, and M94120 Israel) were tested.

In kale, the *Eretmocerus* sp. (M92014 Spain) parasitized the greatest proportion of SPWF nymphs (x=14.9) The *Eretmocerus* sp. (M92019 India) parasitized almost as many SPWF nymphs (x=13.9). None of the three remaining strains parasitized more than 10% of the available SPWF nymphs. The results of the field impact evaluations suggest that *Eretmocerus* sp. (M92014 and M92019) are better adapted to parasitizing SPWF on kale than the *Encarsia* spp. tested. This could be due to the effect of the host plant on the foraging parasite. For example, the native *Eretmocerus* sp. in the desert valleys of California and Arizona does not parasitize significant numbers of SPWF on cruciferous crops. The effect of the host plant kale on the *Encarsia* spp. was also observed in recent mass rearing efforts. Low rates of parasitism were found for the two *Encarsia* spp. M94055 and M93003 when they were reared on kale and collards in the field insectary.

In melons, no significant differences in percent parasitism were found among the eight species/strains tested SPWF numbers were at or near damaging levels very early on in the melon crop. The high numbers of SPWF produced copious amounts of honeydew within the sleeve cage. The environment inside the sleeve may have been too sticky for the parasites to search effectively. For these reasons, sleeve cage evaluations on melons may not accurately depict the potential of the exotic parasites. It is also likely that biological control of SPWF on melons requires the integration of additional biological control agents to be successful.

In cotton, the *Eretmocerus* strains from Pakistan and Spain parasitized significantly more hosts than the other strains. Parasitism rates for these two strains reached approximately 18 %, while the *Eretmocerus* strain from India parasitized about 12%. The remaining two *Eretmocerus* strains from Thailand and Israel parasitized less than 10% of the available hosts.

Results of the entire field evaluation process indicated that the *Eretmocerus* spp. (M92014 Spain, M92019 India, M95012 Pakistan) and *Encarsia* sp. (M94055 Brazil) should be mass reared for field release.

Investigator's Name(s): Andrew Corbett, Jay A. Rosenheim, William Roltsch[1], Charles Pickett[2], Michael Stimmann[3].

Affiliation & Location: Department of Entomology, University of California, Davis, CA 95616; California Department of Food & Agriculture, [1]c/o USDA, 4151 Hwy. 86, Brawley, CA 92227, and [2]3228 Meadowview Rd., Sacramento, CA 95832; and [3]Department of Environmental Toxicology, University of California, Davis, CA 95616.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 to November 1995.

Quantifying the Effect of Early-Season Refugia on Aphelinid Populations Through Elemental Labeling

Our objectives in this project are, through elemental labeling, (1) to determine what proportion of aphelinids (*Eretmocerus* spp. & *Encarsia* spp.) in melon and cotton crops originate from adjacent refuges, and (2) to determine the spatial distribution of aphelinids from refugia. This will provide critical information with which to evaluate the potential of refugia for whitefly management and to determine their optimal implementation.

Refuge strips in two experimental plots at the USDA Irrigated Desert Research Station (Brawley, CA) were sprayed with aqueous rubidium solutions ca. every third week between March 13 and May 23. Each plot consists of three refuge strips bordering 20m wide blocks planted to cotton and melon. On each spray date, each strip was sprayed with a 3000 ppm Rb solution. To assess labeling of aphelinids, leaves having high densities of whitefly nymphs were collected from collard plants within the treated refuge strips, and from untreated strips at another site. We calculate a "threshold", above which an individual is considered to be labeled, as the mean Rb content of aphelinids from untreated refuges plus 3 standard deviations. Here we report results only for *Eretmocerus* spp. The calculated threshold for *Eretmocerus* is 0.20 ng Rb per insect. Thirty percent (29.7%) of *Eretmocerus* from treated refuges had Rb content greater than this threshold, indicating that elemental labeling of this parasitoid was successful.

Eretmocerus spp. have been collected from the adjacent melon and cotton crops using clear vinyl cards coated with vaseline. Cards were placed at varying distances within the crop on a bi-weekly basis starting on April 4 and continuing to May 30. In the first experimental plot, 81 out of 234 *Eretmocerus* analyzed had Rb content greater than the threshold, indicating that a minimum of 35% of these parasitoids had originated from the refuge strips. In the second plot, 42 out of 156 *Eretmocerus* were labeled, indicating that at least 30% of the individuals in this plot had originated from the refuge strips. If we adjust these percentages for the proportion of *Eretmocerus* emerging from refuge strips without labels, then our results suggest that the vast majority of early-colonizing *Eretmocerus* in these plots were from the early-season refugia.

We have successfully labeled aphelinids emerging from early-season refugia. Our results to date have confirmed that refugia contributed significantly to the population of *Eretmocerus* spp. foraging in adjacent melon and cotton crops. Further processing and analysis of samples from the crops will indicate the degree to which refuges are contributing both to populations of *Encarsia* spp. and of whitefly adults.

Investigator's Name(s): Dan Gerling and Rivka Fried.

Affiliation & Location: Department of Zoology, Tel Aviv University, Ramat Aviv, Israel 69978.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Examination of the reproductive behavior of *Eretmocerus mundus* was carried out in order to optimize laboratory rearings and to calculate release rates in whitefly-infested greenhouses. The study included detailed examination and follow up of the reproductive cycles of individual females. Three cultures were used. One was kept in the laboratory for about 6 months prior to the experiments, in the others we used the F1 progeny of field collected material.

The failure of some *Eretmocerus mundus* females from the lab culture to reproduce prompted us to dissect a sample of females immediately upon emergence and to count the number of eggs in their ovaries. It revealed that whereas normal females had always several, and often more than 15 more than eggs in their ovaries, some (the sterile ones) had no eggs at all. In addition, these females had a degenerated reproductive system. Of the field populations, one included a few sterile females, and the other had none.

An examination of the mechanism by which sterility is induced in the females of *Eretmocerus mundus* showed that it is density induced. Females that were kept solitary in the laboratory had only fertile progeny, whereas those that were kept with as many as 10 additional females in each oviposition cage, had 60-100% sterile progeny.

It is not known how wide-spread the phenomenon of induced sterility is, but wherever it occurs, it has profound implications on the rearing procedure of *Eretmocerus mundus*.

Investigator's Name(s): John A. Goolsby[1] & Lloyd E. Wendel[1].

Affiliation & Location: USDA APHIS PPQ, Mission Biological Control Center[1].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Establishment Evaluation of Exotic Parasitoids in the Lower Rio Grande Valley and Wintergarden of Texas

Establishment evaluation is designed to determine which species/populations become established and which are adapted to a regional complex of microclimates and host plants. The adapted exotic parasite species or strains can be prioritized for subsequent mass release and colonization. Releases are made in a structured manner, where each site receives a combination of species which can be morphologically and/or genetically distinguished (DNA patterns) from each other and from the native species. This allows for geographic strains or cryptic species to be isolated from each other for evaluation. Samples are made during and after releases and to measure the percentage of native and exotic parasitoids.

Release sites are selected from both urban and agricultural areas. Sites are selected that contain preferred hosts such as kenaf, melons, okra, eggplant, cabbage, and broccoli in a year round planting schedule. Ideal release sites contain the crop plants listed above plus woody perennial hosts such as, hibiscus and lantana. The sites are designed to be perennial refuges for the natural enemies where adverse factors such as chemical application and drought can be mitigated. Natural enemies can be followed in each location over a long period of time; adapted natural enemies can then be redistributed.

In the LRGV, 890,000 parasitoids representing different 30 species/populations have been released. Several of these species have been recovered they are: *Eretmocerus* spp. (M92104 Spain), (M95012 Pakistan), (M92019 India), (M93005 India), (M94085 Italy), (M94120 Israel); *Encarsia transvena* (M93003 Spain), (M94047 Malaysia); *Encarsia* nr. *hispida* (M94056 Brazil); and *Encarsia lutea* (M93064 Cyprus). The indigenous Encarsia pergandiella continues to make up the largest percentage of all parasitoids reared across sample dates and plant types. Recent recoveries from broccoli and *sonchus* at an organic farm in Donna, TX show the exotic *Eretmocerus* spp. (M95012 Pakistan and M92014 Spain) comprising greater than 25% of the parasitoids reared.

In the TX Wintergarden 50,000 parasitoids representing different 24 species/populations have been released. The Wintergarden is 200 miles northwest of the LRGV and has considerably colder winters. Sweetpotato whitefly populations decline to very low levels during the winter months. Sesame plays an important role in the Wintergarden in the spring build-up of SPWF and can be heavily damaged. Two exotic species *Encarsia transvena* (M93003 Spain) and *Eretmocerus* sp. *nov.* (M94002 Texas) which were released in the Wintergarden in Oct. of 1994 successfully overwintered and were recovered in this fall. This shows that these species of exotic parasitoids can survive temperatures below 0°C and the extremely low host densities experienced during winter months in the Wintergarden.

In conclusion, both establishment evaluation programs were successful in releasing all the permitted parasitoids in locations where they would have the maximum opportunity to become established. Several exotics have been recovered following releases in 1994 demonstrating that they have successfully overwintered. Identification of exotic parasitoids by integrating the use of morphological characters and RAPD - PCR proved to be a very efficient and accurate method of evaluating field establishment. We will continue to monitor the establishment and spread of the exotic parasitoids during FY-96.

Investigator's Name(s): John A. Goolsby and Lloyd E. Wendel.

Affiliation & Location: USDA APHIS PPQ, Mission Biological Control Center.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Importation of Exotic Natural Enemies for *Bemisia tabaci* (Biotype "B")

Twenty one species/populations of *Eretmocerus* and *Encarsia* spp., were established in culture from collections made in the Dominican Republic, Indonesia, Israel, Italy, Malaysia, Pakistan, The Philippines, Spain, Taiwan, and Thailand, and the United Arab Emirates, during 1995. The foreign exploration was conducted by: A. Kirk and L. Lacey (USDA-ARS-EBCL); R. Carruthers, J. Legaspi, Tad Poprawski and W. Jones (USDA-ARS-BCPRU-Weslaco, TX); Mike Rose (Texas A&M); M. Ciomperlik (USDA-APHIS-PPQ-Mission, TX); and E. Porter (US Consulate, Dubai, UAE). Environmental assessments have been completed by federal and state scientists which support the field release of species in the genera *Eretmocerus* and *Encarsia* with uniparental, biparental or autoparasitic biologies.

Natural enemies imported into the MBCC quarantine follow a set protocol which maximizes the number of unique species or biotypes cultured. Natural enemies from collectors are isolated into separate emergence containers by date, geographic location, and host plant. Individuals from each of the different genera or species are isolated from *Bemisia* immatures for analysis. Parasitoid adults from each potential culture are collected for characterization by both molecular geneticists and taxonomists. Individuals from each isolation can be characterized by DNA patterns within days after importation using RAPD-PCR while taxonomic identifications are in progress. The DNA patterns allow us to identify genetically unique populations of natural enemies and avoid duplicate cultures of similar organisms.

Exploration for natural enemies of SPWF has been conducted in the Mediterranean Region, South Central and Southeast Asia, and South America. Many new exotic natural enemies are now in culture and are in the process being evaluated RAPD-PCR has proved to be extremely useful tool in characterizing material imported into quarantine. Several genetically unique populations of parasitoids were identified that would have been indistinguishable using techniques based on morphological characters. It is important to note that genetic markers do not necessarily represent new species, but rather differences that can be used to identify unique populations for rearing and field evaluation.

Investigator's Name(s): John A. Goolsby[1], Jesusa C. Legaspi[2], and Benjamin C. Legaspi, Jr[3].

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center[1], Texas Agricultural Experiment Station, Weslaco, TX[2], and Joint affiliation: USDA-ARS & Texas Agricultural Experiment Station, Weslaco, TX[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Quarantine Screening of Natural Enemies

The purpose of quarantine screening is to determine which species of exotic parasitoids show the greatest potential for suppression of SPWF on selected crops. Tests were devised to measure fecundity per female on SPWF infesting specific crop plants. Results of these tests were used to prioritize which exotic species received emphasis in mass-rearing and release. Melons, *Cucumis melon*; cotton, *Gossypium hirsutus* and broccoli, *Brassica oleracea* were chosen for the screening because of the considerable economic losses occurring annually due to SPWF.

Parasitoids were reared on hibiscus at the USDA-APHIS Mission Biological Control Center (MBCC). Plants were grown in the MBCC quarantine greenhouse facility which was maintained at temperatures and photoperiod similiar to field conditions for each crop. Plants were infested with adult *B. tabaci* and held 2 days for oviposition. Individual melon leaves with moderate egg densities were selected. All adult whitefly were removed from the leaves and then covered with an organza sleeve. Whitefly were held for 14 days until the nymphs reached 2nd and 3rd instars. Two parasite females from each of 19 separate quarantine cultures were released per leaf sleeve with 10 replicates (leaves) per species. Parasitoids were allowed to forage for 2 days and then removed. Leaves were removed from the plant 16 days after introduction of the parasitoids and examined for evidence of parasitism. The numbers parasitized and the percentage parasitism was determined for each of the species tested.

The results of quarantine screening of the newly imported parasitoids indicate there are significant differences in host plant preference. For each plant type there appears to be either a single or small group of species that are appear to be best adapted. The results by crop type are discussed below.

The results of screening on melons indicate that the numbers of whitefly attacked were significantly different among the species/strains tested. *Encarsia* nr. *pergandiella* (Mission quarantine unique # M94055 - Sete Lagoas, Brazil) performed the best in this test and appears to have biological attributes useful to foraging on *B. tabaci* on melons. This parasitoid was originally collected from soybeans, a particularly hairy plant. It is possible that this adaptation to its host is advantageous for foraging on melons which also have hairy leaves.

The results of screening on cotton indicates that there are significant differences in numbers attacked from the species tested. *Eretmocerus* sp. (M95012 Multan, Pakistan) attacked significantly more SPWF than the other 18 species tested. The data from these tests show that the *Eretmocerus* sp. Pakistan has potential for release in cotton. Pakistan is climatically similar to the Lower Rio Grande Valley which may play an important role in the field effectiveness of this species.

The results of screening on broccoli indicates that there are significant differences in the numbers attacked from the species tested. Four populations of *Eretmocerus* and one *Encarsia* attacked the most number of whitefly and were ranked together. The *Eretmocerus* were: M92014 Spain, M94092 Italy, M93005 India, and M95012 Pakistan, and *Encarsia* sp. nov. (parvella group) M95001 from the Dominican Republic. The test was devised to measure fecundity per female on SPWF infesting a crucifer. The test shows that the five exotic parasitoids listed above reproduce significantly better on crucifers than the native species, which may afford the exotic species an advantage in the field.

Investigator's Name(s): D.H. Gouge, T.J. Henneberry, and L.L. Reaves.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Parasitism of *Bemisia argentifolii* (Homoptera: Aleyrodidae) by Entomopathogenic Nematodes in the families Steinernematidae and Heterorhabditidae

The entomopathogenic nematode species *Steinernema feltiae, S. riobravis,* and *Heterorhabditis bacteriophora* were all found to parasitize nymphs of *Bemisia argentifolii.*

The infective juvenile nematodes were sprayed onto cotton leaf surfaces infested with *B. argentifolii* nymphs. Leaves were contained within humidity chambers to increase nematode survival.

The infective juveniles of the steinernematid species appear to be entering beneath the operculum through the vasiform orifice of second and third instar nymphs. Heterorhabditid nematodes are capable of entering insect bodies directly through intersegmental membranes, so either method of entry may be employed by *H. bacteriophora.*

No more than three nematodes were ever seen infecting a single insect and subsequent development of the nematodes within was very rapid. Adults of *S. feltiae,* and *S. riobravis* were recorded after 24 hours of nematode application. The adult females of *S. riobravis* and *S. feltiae* were stunted in growth. However, the "pygmy" forms did produce viable offspring.

Death of the nymph was indicated by development of a red body color. It appears that the red eye pigment becomes disseminated through the cadaver as septicemia of the body tissues occurs.

Adult whitefly were also occasionally infected by the nematodes, but the avenue of infection is unclear.

Unfortunately although *B. argentifolii* can be parasitized by the species of entomopathogenic nematodes tested, infection levels never exceeded 20% of nymphs contained on a leaf.

Investigator's Name(s): James Hagler, John Palting[a], & Javier Enriquez[a].

Affiliation & Location: USDA,ARS, Western Cotton Research Laboratory, Phoenix, AZ; [a]Department of Veterinary Sciences, The University of Arizona, Tucson, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: September 1995 - Present.

A Monoclonal Antibody to *Bemisia tabaci* Nymphal Antigen: A Tool for Predator Gut Analysis

A species- and stage- specific monoclonal antibody for a *Bemisia tabaci* nymphal antigen is being developed. A nymphal-specific protein was isolated by SDS-PAGE. The isolated protein was then injected into BALB/cJ mice using a novel immunization protocol. Anesthetized mice were surgically immunized by injecting the isolated protein directly in the spleen. The immune spleen cells were then used for hybridoma development. Preliminary Western blot assays of the parent hybridomas indicate that several cell lines are responding to the targeted antigen. After cloning, a monoclonal antibody that only recognizes nymphal antigen will be available for testing predator gut contents for nymphal prey remains using an enzyme-linked immunoassay (ELISA). This ELISA will be used in concert with a preexisting egg-specific ELISA to determine the frequency of predation on whitefly eggs and nymphs under realistic field conditions.

Investigator's Name(s): James Hagler and Steve Naranjo.

Affiliation & Location: USDA,ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: June 1995 - Present.

Evaluating the Feeding Behavior of Commercial and Indigenous *Hippodamia convergens* on Sweetpotato Whitefly: A Laboratory and Field Study

Laboratory and field studies were conducted in 1995 to compare the predatory activity of commercial *Hippodamia convergens* with their wild counterparts on sweetpotato whitefly. Laboratory studies indicate that the number of prey consumed, the predator handling time of prey, and predator searching behaviors (i.e., searching, resting, grooming, etc.) were almost identical between commercial and indigenous predators. A monoclonal antibody (MAb) that we have already developed for detection of whitefly egg antigen was used to measure the efficacy of commercial and indigenous predator populations under field conditions. The commercial predators were marked, released into cotton and cantaloupe fields, recaptured, and their gut contents were examined for prey remains by ELISA. Field results suggest that the commercial predators feed on whitefly as frequently as their indigenous counterparts.

Investigator's Name(s): Kim Hoelmer[1], Juli Gould[2] and W. Roltsch[3].

Affiliation & Location: USDA, APHIS, Phoenix Plant Methods Center, Brawley, CA[1] & Phoenix, AZ[2] and CDFA, Biological Control Program, Brawley, CA[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 to December 1995.

Field Cage Evaluations of Non-indigenous Parasitoids in Desert Crops

Evaluations of non-indigenous parasitoids of *Bemisia* were undertaken to identify species that are more effective than native species against whiteflies in key crops grown in desert valleys of California and Arizona. Parent material maintained in culture at the USDA Mission Biological Control Center in Mission, TX, and the California Department of Food & Agriculture in Sacramento was obtained for studies. Each culture has been characterized with a diagnostic PCR pattern by the Mission laboratory.

Replicated releases of *Bemisia* were made into mesh-covered field cages containing seedling field-sown or transplanted melons, cotton, broccoli and alfalfa. When nymphs of suitable age were present, known numbers of female parasitoids were released into each cage, accompanied by males to ensure mating, and the development of their progeny was monitored. Non-release cages served as controls and provided an estimate of the level of contaminating parasitism. Samples were taken to compare production of F_1 progeny as well as to follow subsequent increase in numbers.

In Brawley and Phoenix, *Eretmocerus* spp. M92014 (Spain, PCR pattern Eret-1), M94036 (Thailand, Eret-3), M94023 (Thailand, ex melons, Eret-8), M94120 (Israel, Eret-1) and *Encarsia* spp. M93003 (Spain, En-7), M92018 (India, En-1) and M94055 (Brazil, En-15) were evaluated on spring canteloupes. The greatest number of progeny was produced by M92014 (Spain) in Phoenix and M94120 (Israel) in Brawley. The *Eretmocerus* cultures were otherwise similar and produced significantly more F_1 progeny than any of the *Encarsia spp.*. The uniparental *Encarsia* M94055 was more productive than the autoparasitic species M93003 and M92018, whose performance may have been adversely affected by insufficient numbers of males.

Trials in cotton at Brawley were inconclusive in a comparison of several autoparasitic *Encarsia* due to insufficient levels of whiteflies in cages. In a second Brawley cotton evaluation of three *Eretmocerus* and two uniparental *Encarsia,* high levels of contamination by native species complicated assessment of F_1 production. Identification of the offspring is underway to separate out the contaminants.

Evaluations in broccoli at Brawley compared the *Eretmocerus* spp. M94040 (Thailand, Eret-3), M94120 (Israel, Eret-1) & M95012 (Pakistan, Eret-10) and the uniparental *Encarsia* M94055 (Brazil, En-15) and M94056 (Brazil, En-16). The *Eretmocerus* from Israel (M94120) was the most productive, followed by the other *Eretmocerus. Encarsia* sp. M94056 was more productive than M94055. A second set of evaluations on broccoli by CDFA compared three morphologically indistinguishable autoparasitic *Encarsia transvena* cultures, M93003 (Spain, En-7), M94041 (Thailand, En-5) and M94047 (Malaysia, En-5). Special efforts were made to ensure favorable sex ratios (1:5 male:female) at time of release, and when F_1 pupae were seen, additional females were introduced during two consecutive weeks. The M93003 culture produced more than twice the F_1 progeny than the M94047 and over three times that of M94041. The performance of M93003 was comparable to that of several of the *Eretmocerus* in broccoli. The extra attention given to providing a favorable sex ratio during the study was important in evaluating these autoparasitoids.

Evaluations in alfalfa during late fall compared the *Eretmocerus* spp. M94040 (Thailand, Eret-3), M94120 (Israel, Eret-1) & M95012 (Pakistan, Eret-10) and the uniparental *Encarsia* spp. M94055 (Brazil, En-15) and M94056 (Brazil, En-16). The most F_1 progeny were produced by *Encarsia* M94055 and *Eretmocerus* M94120. Alfalfa is the only crop on which M94055 has performed well relative to other species. Low numbers of whiteflies was a problem, however, and may have adversely impacted the performance of some of these species in alfalfa.

Investigator's Name(s): Kim Hoelmer[1] and James Hagler[2].

Affiliation & Location: USDA-APHIS, Phoenix Plant Methods Center, Brawley, CA[1] and USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ[2].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 to December 1995.

Preliminary Biological Studies of *Semidalis sp.*, a Native Neuropteran Predator of *Bemisia*

Populations of a dustywing, *Semidalis sp.* (Neuroptera: Coniopterygidae), increase as populations of *Bemisia* increase in the fall on many species of ornamental shrubs and trees in urban areas of Imperial County, CA and Yuma, AZ. Larval and adult *Semidalis* consume egg and nymphal whiteflies in large numbers. Although small in size (larvae attain a length of 1 - 1.5 mm, adults are ca. 3 mm in length), by late fall they are very abundant and consume a large proportion of the whiteflies on urban hosts, including many that are parasitized. Pupation occurs within flattened, circular cocoons. During November most larvae stop feeding and spin cocoons in which they overwinter as diapausing larvae.

Observations of the feeding behavior and development of *Semidalis* were initiated in the laboratory. Larvae consumed between 250-275 whitefly eggs per day. When given a choice between whitefly eggs and nymphs as food, larvae preferred to feed on young nymphs, and tended to avoid eggs, fourth instars and pupae. Adults accepted either eggs or younger instars. In an environmental chamber set to a D:N regime of 32:19 °C, eggs hatched in 7-10 days, larvae passed through three to four stadia to pupation in an average of 7 days, and the duration of pupation was 10-20 days.

Gut content assays of *Semidalis* were also conducted to determine whether whitefly egg antigens were detectable by ELISA. Larvae and adults were starved for two or more days or fed honey as negative controls. Diets tested included whitefly eggs only, nymphs only, or both eggs and nymphs together. Larvae that pupated while on one of these diets were assayed separately from those still feeding. Adult dustywings and larvae that were fed on *Bemisia* eggs scored positive in the assays. Adults fed on mixed eggs and nymphs also scored positive for the antigen, while larvae given mixed eggs and nymphs were negative. This corresponds with the lab observations on prey stage preferences. All other groups were negative, including larvae that pupated after feeding on whitefly eggs and larvae that fed only on whitefly nymphs.

Relatively little is known about this group of neuropterans as predators of whiteflies. In view of their impact on *Bemisia* in southeastern California, dustywings merit further attention as biological control agents.

Investigator's Name(s): Walker A. Jones[1] and Tadeusz J. Poprawski[1,2,3].

Affiliation & Location: USDA-ARS, Subtropical Agricultural Research Laboratory, Weslaco, TX[1], Texas Agricultural Experiment Station, Texas A&M University, Weslaco, TX[2], and USDA-APHIS, Mission Biological Control Center, Mission, TX[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Bemisia argentifolii Parasitized by *Eretmocerus* sp. is Immune to Infection by *Beauveria bassiana*

The possibility of using two types of natural enemies that could produce an additive effect on host mortality is the goal of a cooperative research effort. These are the results of the first phase of a series of investigations designed to determine if parasitoids and fungal pathogens are compatible for augmentation against *B. argentifolii* in vegetables. A laboratory test was conducted to determine if *Beauveria bassiana* kills immature native *Eretmocerus* sp. following parasitization across a range of developmental stages within their hosts.

Female whiteflies were confined for several hours within clip cages to the undersides of individual excised sweet potato leaves rooted in hydroponic solution. After 10 d at 27°C, host nymphs were exposed to mated female parasitoids in a large ventilated Petri dish for a few hours (hosts are then a mixture of 2nd and 3rd instars). *Beauveria bassiana*, strain GHA, obtained from Mycotech, Corp., Butte, MT, was applied to the infested leaves at ca. 1000/mm^2 at 1, 2, 3, 9, and 13 d after parasitization. The Texas *Eretmocerus* sp. takes a mean of 17 d to emerge at 27°C. Treatments were: fungus in an aqueous carrier containing 0.02% Tween 80 surfactant, 0.02% Tween 80 solution without fungus, and water alone (control), plus parallel fungus treatments on unparasitized hosts to confirm infectivity potential. Data were recorded on the number of parasitized pupae, number and sex of emerged parasitoids, fungus-infected hosts, and unaffected hosts. Sublethal effects were measured for adults emerged from certain treatments. The longevity of surviving parasitoids was determined by placing newly emerged adults individually into gelatin capsules containing honey. Fecundity during the first four days following emergence was measured for 10 individual females surviving treatments of both the fungus solution and Tween-80 alone applied at 13 d following parasitization.

The results generally demonstrated that following parasitoid egg hatch (day 3 at 27°C), the fungus was unable to colonize parasitized host nymphs. For the 9- and 13-d-old treatments, in which all parasitized hosts were identifiable prior to spray application, no infection of parasitized hosts was successful. Rates of successful parasitism among hosts sprayed at day 3 (most parasitoid eggs eclosed) were similar to those in the controls. Rates of fungus infection at day 1 and 2 were similar to that for unparasitized host cohorts, although significant numbers of parasitoids successfully developed from hosts that apparently escaped fungal infection. Microscopic examination disclosed that spores applied to the cuticle of parasitized nymphs germinated normally and that penetration pegs were present, suggesting that hyphae were killed upon subsequent penetration of parasitized hosts.

Longevity (mean $\pm$ SD) of adults surviving the 3-d-old fungus sprays (5.7 $\pm$ 2.5 d) was significantly lower than those surviving the Tween 80 solution (7.6 $\pm$ 3.6 d). A similar pattern was recorded for the 13 day spray treatment, but no differences were detected in longevity when fungus was applied to hosts containing 9-d-old parasitoid larvae. Fecundity of mated females surviving the 13 d treatments of fungus and Tween 80 was not significantly different, producing 148.1 and 164.2 mean progeny per female, respectively. These results demonstrate that spray applications of *B. bassiana* a few days following release of *Eretmocerus* sp. would enhance overall whitefly mortality in the field while also allowing developing parasitoids to emerge and survive to parasitize additional whiteflies.

Investigator's Name(s): Walker A. Jones and S.P. Wraight.

Affiliation & Location: USDA-ARS, Subtropical Agricultural Research Laboratory, Biological Control of Pests Research, Weslaco, TX.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: Fall 1994 - Spring 1995.

Effects of Fungal Pathogen Applications in Vegetables on the Foraging Activity of Native Parasitoids

Recent research on the applied use of fungal pathogens for management of *Bemisia argentifolii* in field applications has been very promising. The effects of fungal spore applications on non-target species, particularly other natural enemies such as parasitoids, is of interest. We used a new method to measure the activity of naturally-occurring adult parasitoids in plots of cucumber and broccoli in which various treatments of fungal pathogens were applied for control of *B. argentifolii* nymphs. These trials were partly an attempt to assess the utility of a newly developed sampling technique, as well as a supplemental assessment of the effects of fungal sprays on parasitoid activity.

The procedure consisted of placing individual, laboratory-produced, whitefly-infested (sentinel) leaves in field plots for 2-4 days, then returning them to the laboratory for assessment of parasitism. The goal was similar to the use of lab-produced insect egg masses which are routinely placed in the field to assess egg parasitism The development of a successful procedure using excised sweet potato leaves rooted in plastic tubes (floral aquapics) in hydroponic solution was essential to the success of this method. Sweet potato leaves proved to be the best host plant for this purpose, although a technique has now been developed that allows the use of melon leaves. Host density and stage can be manipulated prior to field exposure. Exposed leaves returned to the laboratory are held in ventilated dishes in environmentally-controlled incubators. Ca. 100-300 nymphs were on each leaf. Following recovery from the field plots, exposed leaves were held individually until developing parasitoids could readily be counted. Parasitism was assessed just prior to parasitoid emergence. Emerged adults were also counted to determine sex ratio and confirm species, although this data is not reported here.

Two trials were conducted during fall, 1994, one in cucumber (Trial A) and one in broccoli (Trial B). The treatments were (1) *Beauveria bassiana* @ 2 x 10^{13} conidia/acre, (2) *Paecilomyces fumosoroseus* @ 2 x 10^{13} conidia/acre, (3) and a carrier control, each at 5-d intervals, (4) Capture/Orthene at 10-d intervals, and (5) an untreated control, all with four replications of 0.009 acre test plots of 4 rows X 30 feet. All treatments were made at 30 gal per treated acre. Initial treatments were applied beginning 14 October. Sentinel leaves were placed in the center of each plot, one per plot for 1-4 d intervals on 24-28 Oct., 2-4 Nov., 16-17 Nov., and 28 Nov. - 1 Dec., 1994. Sentinel leaves were removed from plots during spray applications when necessary. Trial B was conducted in a similar manner as Trial A. All applications were made at 30-50 gal per treated acre. Initial treatments were applied 16 November. A second series of trials was conducted in the spring of 1995, but the natural rate of parasitism was too low to assess possible treatment differences.

Percent of sentinel leaves containing any parasitoids, pooled across time for Trial A was: untreated control, 76.9%: *B. bassiana* 75.0%; carrier control 66.7%, *P. fumosoroseus* 66.7%, and Capture/Orthene 45.5%. A total of 911 parasitized hosts were counted in Trial A. The frequencies of parasitized leaves in Trial B in broccoli were: untreated control 83.3%, both the carrier control and *P. fumosoroseus* 58.3%, and both *B. bassiana* and Capture/Orthene mix 33.3%. A total of 598 parasitized hosts were counted in Trial B. *Encarsia pergandiella* was the predominate parasitoid species, composing 91.9% of all emerged parasitoids in Trial A; 75.6% in Trial B. *Eretmocerus* sp. (south Texas sp.) composed the rest. In Trial A, the mean number of *E. pergandiella* per parasitized leaf was 21.7 in the untreated control, 18.8 in the carrier control, 11.2 and 13.8 in the *B. bassiana* and *P. fumosoroseus*, respectively, and 2.8 in the insecticide plots. In Trial B, *E. pergandiella* averaged 24.4 parasitized hosts per leaf in the untreated control plots, 5.4 in the carrier control, 3.4 and 4.8 in the *B. bassiana* and *P. fumosoroseus*, respectively, and 0.1 parasitoids per parasitized leaf in the insecticide treated plots. The data will be combined with that obtained from current trials.

Investigator's Name(s): Alan Kirk, Lawrence Lacey.

Affiliation & Location: USDA, ARS, European Biological Control Laboratory, Montpellier, France.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Efficacy of *Clitostethus arcuatus* a predator of *Bemisia argentifolii*

Clitostethus arcuatus (Coleptera: Coccinellidae) collected from *Trialeurodes vaporariorum* on *Lantana camara* in south east Spain in 1994 has been successfully reared on *Bemisia argentifolii* on cabbage.

Adults and larvae of the beetle were collected in the town of Mazzaron in the arid south east of Spain. Here temperatures are very high in summer (>40°C) and low in winter (down to -4°C). Rainfall is sporadic, occurring mainly in early summer and fall (230 mm annually) which makes this one of the driest parts of Europe.

While collecting the beetles, it was observed that both larvae and adults actively trapped and ate adult Wfs. This unusual habit was studied in preliminary laboratory experiments. Adult beetles were able to survive and oviposit on a sole diet of *Bemisia* adults. In addition all WF stages were consumed by adult and larval beetles.

These results indicate that *Clitostethus* could be well adapted for a niche in which WF adults are present in large numbers, e.g., a newly landed migratory population, overwintering WF populations, or directly after mass emergence of WF adults.

Preliminary results of the application of two times the *B. tabaci* LC_{95} of *Paecilomyces fumosoroseus* spores onto adult beetles resulted in no infection. Under favorable conditions for a fungal pathogen, the predator may enhance its efficacy by acting as a fungal transporter.

Further experiments on the efficacy of *Clitostethus* as a predator of *Bemisia* will be reported on later.

Investigator's Name(s): Alan Kirk[1], Lawrence Lacey[1], Susie C. Legaspi[2], Raymond Carruthers[2], Dave Akey[3].

Affiliation & Location: USDA-ARS, European Biological Control Laboratory, Montpellier, France[1]; USDA-ARS, Biological Control of Pests, Weslaco,TX[2]; USDA-ARS-WCRL, Phoenix, AZ[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Foreign exploration for Silver leaf whitefly natural enemies.

An *Eretmocerus sp.* (M95012) was reared from SLWF infested *Hibiscus* collected in Multan (Punjab) Pakistan in April 1995. The parasitoid is being maintained and produced at the APHIS Mission Biocontrol Center. Results of host suitability screening on cotton indicate that this parasite has significantly greater potential for attacking whiteflies than any other whitefly parasitoid currently held in the Mission quarantine. Releases of the Pakistan parasitoid, were begun in fall 1995 in California and after field cage studies at the APHIS Phoenix Methods Laboratory, will be released in Arizona and California in spring 1996. The species has been selected by Mission Biological Control Center as one of the key exotic natural enemies in the Demonstration of Biological Control Based IPM of SLWF in the Rio Grande Valley TX.

Further collections were made from SLWF on cotton and eggplant around Multan in November. Two species of *Eretmocerus* emerged from this material in the APHIS Mission Biocontrol Center TX. In addition and surprisingly, as there had not been rain for several weeks in the area, the fungal pathogen *Paecilomyces fumosoroseus* was found infecting adult and nymphal *Bemisia*. Isolates of this fungus have been cultured and archived at EBCL in Montpellier and were subsequently shipped to the ARSEF collection in Ithaca NY.

Six shipments of natural enemies were made in May/June 1995 to the APHIS Mission Biocontrol Center TX. from Taiwan, Thailand, Malaysia and Indonesia. The highlights of this extensive collection from 19 plant hosts were: Taiwan; a fast growing *Paecilomyces fumosoroseus* strain from *Bemisia* on cabbage, and a uniquely DNA banded *Eretmocerus* sp. from *Bemisia* on *Ambrosia* sp. Indonesia: Four *Encarsia* spp. Malaysia: Coccinellid predator spp. Thailand: an *Eretmocerus* sp. and an *Encarsia* sp.

Most host plants found in Indonesia were infested with the Greenhouse Whitefly *Trialeurodes vaporariorum* and the Spiralling whitefly *Aleurodicus dispersus*. Despite excellent conditions for fungal pathogens in Indonesia, (high humidity and warm temperatures) none were found.

Investigator's Name(s): Alan Kirk[1], Lawrence Lacey[1], John Goolsby[2], Matthew Ciomperik[2], W. Able[3], C. Pickett[4], J. Gould[5].

Affiliation & Location: USDA-ARS, European Biological Control Laboratory, Montpellier, France[1]; APHIS/PPQ, Mission Biological Control Center, TX[2]; APHIS/PPQ, Bakersfield, CA[3]; CDFA, Sacramento, CA[4]; APHIS/PPQ Methods, Phoenix, AZ[5].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1992-95.

Results of foreign exploration for parasitoids of SLWF

More than one hundred shipments of SLWF natural enemies were sent to the quarantine at the APHIS/PPQ, Mission Biological Control Center, TX by scientists from the ARS European Biological Control Laboratory and oversease collaborators.

Sixteen countries in S. America, Mediterranean, Middle East, Indian sub-continent and SE Asia have been explored once or several times for SLWF natural enemies. Parasitoids have been reared from WF spp (SLWF, SPWF, GHWF) infesting forty-three plant hosts.

Seventeen *Encarsia* spp. and eight *Eretmocerus* spp. have been brought into the Mission Biological Control Center quarantine. In addition four predator spp. the Coccinellidae *Serangium* sp. *Serangium parcesetosum*, *Clitostethus arcuatus* and the Drosophilid *Acletoxenus formosus* were collected from Malaysia,India Spain and Crete respectively.

The natural enemy collections have also helped to elucidate the taxonomic status of the *Encarsia* and Eretmocerus spp worldwide. Whiteflies from most of the collections have been characterized which has led to a global view of the distribution of the SilverLeaf Whitefly.

Evaluation of the collected parasitoids has shown that distinct strains exhibit biological parameters adapted to temperature and humidity (the Nile strain of *Encarsia formosa* is more efficient at higher temperatures and lower humidity (the conditions of the Nile delta region) than the *E. formosa* strain from northern Greece (Continental conditions). Evaluation of the Eretmocerus mundus from southern Spain showed that it was more tolerant of selected pesticides than *Eretmocerus* spp. from the USA. In tests on SLWF on cotton, the recently collected *Eretmocerus* sp. from Pakistan parasitized a higher percentage of SLWF nymphs than any other parasitoid thus far evaluated.

Releases of *Eretmocerus* and *Encarsia* spp. have been made in CA, AZ, TX, FL, NH, NY, HI. Three species have been chosen by the Mission Biological Control Center as key exotic natural enemies in the MBCC Demonstration of Biological Control Based IPM program; *Eretmocerus* sp. from southern Spain, *Eretmocerus* sp. from Pakistan and *Encarsia* nr. *pergandiella* from Brazil. Twelve parasitoid species have been permitted for release and 35 species/geographic strains are currently in the quarantine at MBBC.

Investigator's Name(s): L.A. Lacey[1], A.A. Kirk[1] and D. Akey[2].

Affiliation & Location: [1]USDA-ARS, European Biological Control Laboratory, Montpellier, France; and [2]USDA-ARS, Western Cotton Research Laboratory, Phoenix, Arizona.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Application of *Paecilomyces fumosoroseus* using an irrigation system for control of *Bemisia argentifolii*

Blastospores of *Paecilomyces fumosoroseus* were grown in a complex medium (Jackson medium) containing Casamino acids, glucose and vitamins on a rotary shaker (300 rpm, 24°C for ca. 85 h) and applied in a fine mist to cabbage plants at 10^5, 5 x 10^5 and 10^6 blastospores/ml during a one minute period (until runoff) using a modified irrigation system.

The application system consisted of a series of misting nozzles arranged to spray the underside of most leaves from 2 sides at 6 bars pressure. A reservoir containing blastospores in suspension was connected to the irrigation system, such that the main source of water could be temporarily bypassed thereby enabling application of specific concentrations of blastospore suspensions. Humidity was maintained at 85-95% for at least 12 hours/day using misting nozzles and temperature at 24-28°C using heaters or airconditioners.

At the time of application, the whitefly nymphs were predominantly in the second and third instar, but first and fourth instars were also present. Counts of whitefly adults and mortality in nymphs was assessed 5 and 6 days, respectively after application. Mortality for two treatments at 10^5 blastospores/ml was 57 and 67%. Mortality for treatments at 5 x 10^5 and 10^6 blastospores/ml was 67 and 86%, respectively. Less than 1% of treated nymphs showed patent signs of infection with *P. fumosoroseus*. In addition to mortality produced in nymphs, sprayed plants were significantly repellent or at least not attractive to adult whiteflies compared to unsprayed plants.

The extreme water repellency of the cabbage plants necessitated the addition of a wetting agent (Kinetic at 0.25-0.5%) to the blastospore suspension. Due to the already "wetted" condition of blastospores, the necessity to add wetting agents to irrigation water for application of *P. fumosoroseus* to plants that are not inherently water repellent (*e.g.* tomatoes, cucurbits) will be reduced or eliminated. Maintenance of relative humidity equal to or greater than 95% during at least the first 24 h post treatment will undoubtedly improve the efficacy of *P. fumosoroseus* in this system. This and other objectives will be addressed in 1996 in Montpellier.

Investigator's Name(s): L.A. Lacey[1], A.A. Kirk[1], and D.H. Akey[2].

Affiliation & Location: [1]European Biological Control Laboratory, USDA-ARS, Montpellier, France; [2]USDA-ARS, Western Cotton Research Laboratory, Phoenix, Arizona.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Experimental Application of the Fungus, *Paecilomyces fumosoroseus*, Using an Irrigation System in a Greenhouse for the Control of *Bemisia argentifolii* on Cabbage

Blastospores of *Paecilomyces fumosoroseus* (Pfr) were grown in a complex medium (Jackson medium) containing Casamino acids, glucose and vitamins on a rotary shaker (300 rpm, 24°C for ca. 85 h) for application as treatments against the silverleaf whitefly *Bemisia argentifolii* on cabbage plants at 10^5, 5 x 10^5 and 10^6 blastospores/ml. Three treatments were applied in 2 trials. Treatments consisted of 2 different blastospore concentrations and a water control. All treatments contained the adjuvant, Kinetic,0.5%-1st trial, and 0.25 %-2nd trial (0.1 25% was insufficient to wet the cabbage leaves). Each of the 3 treatments was applied in an isolation chamber, constructed of netting, and designated for a specific treatment. The application system consisted of modifications to common European (French) greenhouse irrigation systems for drip and misting of plants. All components (primarily Gardenia parts) were readily available at hardware and nursery stores. Modifications were as follows: 1) a reservoir containing blastospores in 20 liters of suspension was connected to the irrigation system, such that the main source of water could be temporarily bypassed thereby enabling application of specific concentrations of blastospore suspensions, 2) a variable speed electric pump (Peugot 890) capable of producing 90 psi was placed in-line following the reservoir, 3) equal length hoses were led from a block of valves to each of 3 chambers within the greenhouse, 4) each chamber contained a bench on which irrigation pipe ran down the outer edge of the long dimension of the bench, and 5) these two parallel lateral pipes had a series of misting nozzles inserted (ca 45° angle from bench surface) to spray upper and lower surfaces of most leaves. Fifteen or 16 plants were arranged in a staggered row lengthwise in the center of the bench. In the 1st trial, the application of the lower blastospores concentration was applied at 56 psi and the other 2 applications at 59 psi. In the 2nd trial, the control application was applied at 74 psi and the 2 blastospore treatments at 76 psi. Treatments were applied with enough volume to obtain "run off". In the 1st trial, the system was not pre-charged with the treatment liquid but was in the 2nd trial. Volumes applied ranged from 690-1690 ml. Humidity and temperature were maintained at 85-95% and 23-28°C using misting nozzles and heaters. At the time of application, the whitefly nymphs were predominantly in the second and third instar, but first and fourth instars were also present. Counts of whitefly adults and mortality in nymphs and was assessed 5 and 6 days, respectively after application. Mortality for 2 treatments at 10^5 blastospores/ml was 57 and 67%. Mortality for treatments at 5 x 10^5 and 10^6 blastospores/ml was 67 and 86%, respectively. Less than 1% of treated nymphs showed patent signs of infection with Pfr. In addition to mortality produced in nymphs, sprayed plants were significantly repellent or at least not attractive to adult whiteflies compared to unsprayed plants. This effect was observed and recorded 4 days post treatment in both trials. In the 1st trial, the control treatment had a mean of 12.6 adults/plant, the lower blastospores concentration had 0.5 adults/plant, and the higher blastospores concentration had 1.4 adults/plant (however, plants in this treatment suffered leaf damage from the 0.5% adjuvant). In the 2nd trial, the control treatment had a mean of 5.2 adults/plant, the lower blastospores concentration had 2.1 adults/plant, and the higher blastospores concentration had 3.3 adults/plant. The means of adults/plant for the controls in both trials were significantly different from the treatments with blastospores at $P<0.05$. Additionally, in trial 1, fungus was observed on dead adults. The extreme water repellency of the cabbage plants required the addition of the wetting agent (Kinetic) to the blastospore suspension. Treatments for plants that are not inherently water repellent (e.g. tomatoes, cucurbits) will be unlikely to require additional wetting agents because of the already "wetted" condition of blastospores.

Investigator's Name(s): M.A. Latheef, J.B. Carlton, and I.W. Kirk.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: July 1, 1995 - September 30, 1995.

Aerial Electrostatic Charged Sprays for Control of Sweetpotato Whitefly in Cotton

Aerial electrostatic charged sprays were compared with conventional sprays for season-long control of sweetpotato whitefly (SWF) (strain B) on cotton during the1995 season at Maricopa, AZ. Electrostatic sprays of endosulan + amitraz and fenpropathrin + acephate applied at 0.84 + 0.28 and 0.22 + 0.56 kg active ingredient (a.i.) rates per ha, respectively, reduced SWF adults to a level comparable to that of conventional sprays applied at the same a.i. rate. The spray mixture rates for electrostatic charged and conventional sprays were 4.68 and 46.8 L/ha, respectively. Electrostatic charged sprays of esfenvalerate + profenofos applied at 0.056 + 0.56 kg a.i. per ha reduced SWF adults significantly greater than conventional sprays. However, electrostatic charged sprays of bifenthrin + acephate applied at 0.089 + 0.56 kg a.i. per ha had significantly higher SWF adult counts compared to conventional sprays. Seasonal means of viable eggs and live large nymphs (averaged over eight spray applications) in electrostatic spray charging protocol at the full label rate were not significantly different from those in conventional protocol. Seasonal means of viable eggs and live large nymphs in electrostatic spray charging protocol at one-half label rate were significantly the highest among all treatments. LC_{50}s for electrostatic charged and conventional spray applications with fenpropathrin + acephate were comparable. Susceptibility of SWF adults to fenpropathrin + acephate decreased 35-fold after four consecutive applications of the mixtures. The data suggest that the potential for electrostatic spray charging technology as a practical application method is substantial, and that with additional research, this technology could be moved closer to commercialization.

Investigator's Name(s): Tong-Xian Liu and Philip A. Stansly.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Oviposition and Survivorship of *Encarsia pergandiella* (Hymenoptera: Aphelinidae) in Four Instars of *Bemisia argentifolii* (Homoptera: Aleyrodidae)

Oviposition and mortality of *Encarsia pergandiella* Howard in the four instars of *Bemisia argentifolii* Bellows & Perring were evaluated in choice and no-choice tests. Whiteflies and parasitoids were maintained in an air-conditioned greenhouse on potted tomato, sweet potato, collard, and hibiscus. Rooted sweet potato leaves were used to maintain whitefly nymphs exposed to *E. pergandiella* in large cages (60 by 60 by 80 cm) or 0.9 liter clear, plastic cup cages. Experiments were conducted in an air-conditioned insectary at 26.7 Å 2%C , 55 Å 5% RH and photoperiod at l4:10 (L:D) h. *No-choice.* When nymphs had developed to the desired stage, 5 female parasitoids were introduced into each cage for 48 h. Following a 2-wk incubation period, whiteflies were examined to determine number parasitized, living and unparasitized, dead or emerged. *Two-instar Choice.* Five combinations of whitefly host instar were tested: 1st versus 2nd, 1st versus 3rd, 2nd versus 3rd, 2nd versus 4th, and 3rd versus 4th. Both instars were provided on the same leaf by collecting whitefly eggs inside a clip cage at 3 to 9-d intervals. Five parasitoid females were introduced into the cup-cage for a 48 h after desired host stadia were attained. *Multiple-instar Choice.* Whitefly eggs were collected four times on different parts of the same sweet potato leaf at 3 d intervals to present all 4 instars to parasitoids on the same leaf. Alternately, 5 sweet potato leaves, each bearing approximately equal number of the same whitefly stage (egg, 1st, 2nd, 3rd and 4th instars) were arranged in a 15 cm circle inside a large cage. Female wasps (25) were introduced in a glass eye-dropper placed upright in the center and allowed access to the whitefly-bearing leaves for 48 h.

E. pergandiella oviposited in all four instars of *B. argentifolii*, although there were differences among hosts in oviposition rate, preference, and subsequent development time of the parasitoid. Adults emerged from whitefly 4th instars or "pupae" regardless of host stage at oviposition. *No-choice test.* Significant differences among whitefly instars were due primarily to less parasitization of 1st instars (17.5%) compared with older instars. Greatest apparent mortality of parasitoids (13.5%) was observed in 1st instar hosts. Mortality of non-parasitized hosts was more than 3 times greater than of other host stages. *Two-instar choices.* Parasitization of 1st and 2nd instars was significantly lower than older instar hosts. No-choice controls were similar except for less pronounced differences, especially between 2nd and 3rd instars. Only mortality of unparasitized 1st and 2nd instar whiteflies was significantly different, 30.0% vs 18.0%, respectively. *Multiple-instar choice.* Greatest differences in parasitism rate were observed when all instars were available on the same leaf: greatest in 3rd and 4th instars followed by 2nd and then 1st instars. Apparent mortality of parasitoid immatures did not differ significantly among host instars, although greater mortality of 1st and 2nd instar hosts compared to 3rd or early 4th instars was observed. Fourth instars were preferred to all other host stages on different leaves and parasitization of 2nd and 3rd instars was statistically indistinguishable. Again, no signficant differences were observed in apparent mortality of parasitoids among host instars, nor in survivorship among unparasitized host instars, mortality of 1st instars exceeded 4th instars numerically. In summary, *E. pergandiella* oviposited in all nymphal stages of *B. argentifolii,* but preferred the older 2 instars. As parasitoid pressure increased, oviposition in younger instars increased, but with consequences of increased parasitoid mortality, increased host morality, and delayed parasitoid development to allow for growth and maturation of the host (see accompanying abstract). Thus the parasitoid demonstrated behavioral and physiological plasticity enabling it to optimally exploit host resources under a broad gamut of abundance conditions.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Development of *Encarsia pergandiella* (Hymenoptera: Aphelinidae) in Four Instars of *Bemisia argentifolii* (Homoptera: Aleyrodidae)

Whiteflies and parasitoids were maintained in an air-conditioned greenhouse on potted tomato, sweet potato, collard, and hibiscus. Rooted sweet potato leaves were used to maintain whitefly nymphs exposed to *E. pergandiella*. Leaves were held in 0.9 liter clear, plastic cup cages. All experiments were conducted in an air-conditioned insectary at 26.7 ± 2%C , 55 ± 5% RH and photoperiod at l4:10 (L:D) h. Whitefly eggs were collected and monitored on rooted sweet potato leaves as described above until the appropriate nymphal stages were attained. Five parasitoid females were allowed access to nymphs in a cup cage for 24 h. Nymphs were examined daily beginning the 7th day after exposure to parasitoids, and those with displaced mycetomes or visible parasitoid larvae were marked by circling with a ball point pen. Thereafter, development of parasitized nymphs was observed daily until all parasitoids had emerged or died. A total of 66 female parasitoid pupae was initiated in first instars, 53 in second instars, 108 in third instars, and 113 in fourth instars. Parasitoids that did not emerge from these marked whiteflies were considered dead, as were apparently unparasitized whiteflies that did not emerge. For development of males, female parasitoid pupae approximately 24 h old were obtained from whiteflies parasitized as third and fourth instars and exposed to young (< 48 h) unmated parasitoid females in a cup cage for 24 h. Female pupae in which the male larva was recognizable (n = 62) were marked 4 to 5 d after exposure and observed daily thereafter until all live parasitoids had emerged.

E. pergandiella females initiated in all four instars of their whitefly hosts developed successfully, albeit not at the same rate. The earlier the instar parasitized, the more time was required to complete development: almost 50% more for first instars than for fourth instars. The delay corresponded approximately to the time required for the whitefly host to develop to third instar. Development rate of male parasitoids was similar to females initiated in third instar hosts: 9.14 d (SE = 0.14 d) for egg and larval stages and 3.90 d (SE = 0.11 d) for the pupal stage, giving a total of 13.04 d (SE = 0.15 d) from egg to adult (n = 77). There were no significant effects of host stage on survivorship of parasitoids during the late larval-pupal stage. Emergence was 89.6% over all host stages for females, and 83.9% for males. Our results with *E. pergandiella* are consistent with the hypothesis that hatching and/or early larval development of *E. pergandiella* deposited into first or second instars was delayed until the host developed to third instar.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Pupal Orientation and Emergence of Some Aphelinid Parasitoids of *Bemisia argentifolii* (Homoptera: Aleyrodidae)

Native *En. pergandiella* from southwest Florida naturally parasitized a greenhouse colony of *B. argentifolii* were collected from several host plant species, including collard, hibiscus, tomato, and sweet potato. *En. formosa* originally from Beltsville, Md. was collected from a colony of *B. argentifolii* on poinsettias in California. Adults parasitoides were allowed to emerge and then introduced into a large cage enclosed with 52 mesh screen containing infested potted eggplants. Parasitized pupae were collected, and parasitoid development and emergence recorded using a video recorder, and viewed on a monitor connected with a camera mounted on a stereo microscope. Pupal orientation on abaxial and adaxial leaf surface were compared. Additionally, pupae of 5 exotic species: *Eretmocerus* sp. from Hong Kong; *Eretmocerus* sp. A. from Padappai, India; *En.* nr. *pergandiella* from Sete Lagoas, Brazil; *En. formosa* from Nile Delta, Egypt; *Er. mundus* were observed under a stereo microscope, or by detaching whitefly puparia from the leaf surface and fixing to a microscopic slide with double-coated cellophane tape. Dissections were made using two 000 insect pins mounted on applicator sticks.

After positioning itself head forward in the host puparium, pre-pupae of *En. pergandiella*, *En. formosa*, and *En. transvena* commenced a series of undulating motions excreting meconium inside the lower, lateral margins of the host remains. Ten to 35 minutes was required for the completion of a defecation cycle, each resulting in deposition of a meconium pellet for a total of from 2 to 4 pellets on each side. The exarate pupa of Encarsia *spp.* excreted a fluid inside the pupal case just prior to eclosion *in situ*. The fluid appeared to serve as a lubricant and a solvent helping the pharate adult struggle free from pupal exuvia. Most (98%) female *En. pergandiella* pupae from Florida, *En. formosa* from Maryland, Georgia and Egypt, and *En. transvena* from Florida observed on abaxial leaf surfaces developed facing the venter of the host puparium except for *En.* nr. *pergandiella* from Brazil which developed facing the dorsum of the host. All species of *Eretmocerus* faced the host's dorsum. Male *En. pergandiella* pupae faced the dorsum of the host puparium. Of 254 *En. pergandiella* pupae from Florida on adaxial leaf surfaces of 19 eggplant and tomato leaves, only 5 (2.0%) faced the dorsum as did 100% of all *En. formosa* from Maryland. We could not discern any consistent color variation in *En. pergandiella* female adults corresponding to their orientation as pupae in either the rare dorsum-facing or backward (parasitoid head toward posterior of the host) positions. However, dorsum-facing pupae were apparently light-colored because the dark sternum faced the host venter. Rotation of the pharate female *En. pergandiella* to a venter-up position followed side to side movements lasting 10-60 min. Rotation was accomplished in 25 to 98 minutes by first the front legs and later the middle and hind legs pushing against the side wall of the host puparium with increasing vigor so that the thorax and lastly the abdomen was pulled around. After a few minutes to adjust appendages, emergence began with synchronous movements of head and front legs which thrust the working mandibles against the host puparium wall which was soon pierced. Debris accumulated around the edge of the hole as the wasp chewed along the perimeter, enlargeing the opening to free the head and front legs for ever more vigorous movement. Once emerged, the wasp remained motionless on top of the whitefly puparium for 2-15 m allowing the cuticle to dry and harden. Grooming on or off the host remains commenced first with hind legs sweeping alternatively over the upper and lower wing surfaces. Later antennae, mouthparts, and neck and middle legs were groomed by front legs, whereas the middle legs were used to groom hind legs. More than 40 min were spent grooming the wings, and 6 min each for the antennae and legs during the first hour after emergence.

Investigator's Name(s): Heather J. McAuslane & Ru Nguyen[1].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January - December 1995.

Reproductive Behavior and Biology of a Thelytokous *Eretmocerus* sp. (Hong Kong)

Eretmocerus sp. is a thelytokous parasitoid collected by F.D. Bennett in Hong Kong on July 13, 1992. Morphology during development in *B. argentifolii* on hibiscus was studied under laboratory conditions. Eggs were usually deposited at the insertion of the mouthparts into the leaf. Eggs hatched and first instars entered the venter of the whitefly once the host had reached the 4th instar. The brown egg capsule was visible on the venter of the whitefly after the parasitoid larva entered. Parasitoids developed into globose larvae, growing to displace the mycetomes and eventually consuming the entire whitefly. No further development of the whitefly occurred after moult to the 4th instar. Prepupae formed, then pupae which changed color from clear to deep yellow with ruby eyes over a 3-d period. Parasitoids pupated facing the dorsum of the whitefly host with their heads pointing in the same direction as the whitefly.

Host searching and acceptance behaviors were studied using a videocamera system attached to a microscope. The following behaviors were observed and quantified: host feeding, walking, antennating while walking, antennating host, probing, resting, grooming, and performing a post-oviposition "dance" (noted for other *Eretmocerus* species, and assumed to be some form of host marking behavior). Parasitoids laid eggs under 1st, 2nd, 3rd, and 4th instars but 2nd and 3rd were preferred to the other 2 instars. Host feeding occurred on all instars but was most common on 4th instars.

Longevity of parasitoids fed honey or allowed access to leaf discs infested with whitefly nymphs was determined in an environmental cabinet maintained at 14:10 (L:D) h, 28°C day, 24°C night and 75% RH. 80 newly parasitoids were placed individually in 9-cm-diameter petri dishes with screened lids. Dishes were sealed with parafilm. Parasitoids fed honey lived an average of 12.5 d (ranging from 3 to 21 d), while parasitoids with access to hosts lived an average of 7.9 d (ranging from 1 to 17 d).

Age-specific fecundity was assessed for 10 parasitoids for their first 9 d of life. Parasitoids laid an average of 20 eggs per d for the first 6 d of life and then about 10 per d. On the first 3 d of life, parasitoids host fed on about 5 nymphs. Total lifetime fecundity was assessed for 17 parasitoids. Single females caged on 6-leaf hibiscus plants produced 92.8 ± 33.8 (mean ± SD, ranging from 3 to 147) progeny (all female) in their lifetimes.

Developmental period of *Eretmocerus* on 1st, 2nd and 3rd instars was determined. Preliminary data indicated that parasitoids did not develop if oviposition occurred under 4th instars. Emerged whiteflies and parasitoids were aspirated, and whitefly and parasitoid exuviae were counted and removed from the plants daily. Developmental period was shortest in 3rd instars (16.43 d, n = 293 parasitoids), then 2nd instars (16.84 d, n = 245), and longest in 1st instars (17.61 d, n = 376). On average, 86.1 ± 7.9% of whiteflies on 1st instar-infested plants (n = 5 plants) produced parasitoids compared to 88.2 ± 14.8% on 2nd instar-infested plants (n = 4), and 68.0 ± 21.2% on 3rd-instar infested plants (n = 5).

Investigator's Name(s): O.P.J.M. Minkenberg, H.J. Henter[1], J. Hall[2], R.M. Campos[2], C. Leonard, R. Malloy, C. Zhang and S. Penn[3].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: December 1994 - December 1995.

Evaluation of a Native *Eretmocerus* for Inundative Biological Control of Whitefly on Greenhouse Poinsettias

Mass-rearing of *Eretmocerus*: We have made steady progress in producing the native whitefly parasitoid *Eretmocerus* near *californicus* ex. Arizona at the University of Arizona north campus (Beneficial Insectary is now sponsoring the mass-rearing). The yearly total number of wasps produced in 1993, 1994 and 1995 was 9.6 million, 30.8 million and 29.9 million, respectively. We also achieved a dramatic increase in the numbers shipped to various cooperators during 1993-1995, viz, 0.9 million, 3.5 million, and 10.1 million respectively. Parasitoid production will continue in 1996 and large numbers are available for research (please phone 520-321-7714).

Objective: Our main objective is to evaluate inundative releases of this *Eretmocerus* for biological control of sweetpotato/silverleaf whitefly, *Bemisia* sp., on greenhouse poinsettias in the Southwest. Various studies including trials with commercial growers, by Hoddle, Van Driesche and Sanderson have confirmed that this *Eretmocerus* is a better agent than *Encarsia formosa* ex. Beltsville and they have demonstrated its effectiveness against whiteflies on greenhouse poinsettias in the Northeast. Herein we report on two studies to examine the effectiveness of *Eretmocerus* in a warm climate.

Paul Ecke Ranch trial: An inundative release program was run in a half-acre greenhouse during September through November 1994. The greenhouse contained about 10,000 pots with 1-3 plants each and was part of a variety test. We had 100% infestation at the beginning i.e., each plant has at least one whitefly whether this was the egg or adult stage; the average density was 1.6 ± 0.2 adults/pot and 1.2 ± 0.5 pupae/pot. The weekly release rate was 3.4 female wasps per pot. After about three weeks, two applications of soap had to be applied, which reduced the immature and adult whitefly population by over 50% but also greatly reduced the density of adult wasps. Parasitism in samples 3, 4 and 5 was 72%, 45% and 34%, respectively. A cage study showed that *Eretmocerus* significantly suppressed the population of *Bemisia* immatures (release cages: 91.8 ± 17.1 vs. `control' cage: $221.3 \pm 17.1$ nymphs/leaf). Whitefly mortality exclusive of parasitism in the release cage ($8.7 \pm 2.9$%) was similar to that in the `control' cage (12.5 ± 2.9%). It appears that the main cause of whitefly mortality due to *Eretmocerus* is parasitism rather than host feeding, which differs from findings in the Northeast studies. The trial was not successful partly because the initial whitefly density was too high and the parasitoid release rate was relatively low, given the size of the plants at the beginning.

Tucson greenhouse experiment: we conducted a replicated cage experiment to examine effectiveness of *Eretmocerus* from April through July. Daily maximum temperature increased from approximately 22°C. up to 33°C. Average plant size increased from circa 10 leaves up to over 80 leaves. The average weekly release rate was 7.6 ± 2.9 females/plant in the release cages. *Eretmocerus* significantly suppressed the *Bemisia* population in the release cages (mean density of adult whiteflies: 10.8 ± 3.3 vs. `control' cage: $1,891.3 \pm 504.1$ on July 20). In addition, densities of nymphs and pupae per leaf did not significantly change over time in the release cages, whereas the average density of adult female wasps decreased from over 0.12/leaf to circa 0.02/leaf. Accordingly, mean percentage parasitism decreased from 85.4% on June 15 to 42.6% on July 26. We conclude that (1) *Eretmocerus* suppresses *Bemisia* populations and (2) high release rates (> 7 females/plant) are required to achieve effective biological control in the Southwest.

Investigator's Name(s): Steve Naranjo and James Hagler.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1994 - Present.

Characterizing and Estimating the Effect of Heteropteran Predation

Heteropterans often are the numerically dominant species in the predator complexes of many agricultural systems, yet we have only a rudimentary knowledge of how they function in pest control. Our inability to predict the effect of these and other arthropod predators on pest population dynamics remains the most significant barrier to using predators as components of pest management systems. This problem stems in large part from the difficulty of measuring the activity of predators under field conditions. Serology has a long history in the study of insect predation and it is one of the few methods that requires only minimal disruption of the system under examination. We used monoclonal antibodies developed to recognize egg antigens of pink bollworm, *Pectinophora gossypiella*, and sweetpotato whitefly, *Bemisia tabaci*, Strain B (= *B. argentifolii*), to study the native predators of these pests in cotton. Using a multiple-gut ELISA (enzyme-linked immunosorbent assay) we tested more than 22,000 individuals of seven species of predaceous Heteroptera over two field seasons in central Arizona. Based on the frequency of positive ELISA responses and population densities, *Orius tristicolor* and *Lygus hesperus*, a recognized pest species, were found to be the dominant predators of pink bollworm and sweetpotato whitefly eggs. *Geocoris pallens*, *G. punctipes*, *Nabis alternatus*, *Sinea confusa*, and *Zelus renardii* appear to be minor predators of these egg pests. We propose a new predation model that integrates the results of ELISA, predator population densities and functional response behaviors. Preliminary analysis of pink bollworm egg predation suggests that the heteropteran predator complex was responsible for removing approximately 20% of all pink bollworm eggs over the entire season. This effect was achieved at extremely low (and atypical) densities of this pest. We will be applying this predation model to whitefly predators in the near future.

Investigator's Name(s): Steven E. Naranjo and C. C. Chu.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, Phoenix, AZ.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: April 1994 - October 1995.

Effects of Insecticidal Management of *Bemisia* on Populations of Natural Enemies

Studies were conducted in 1994 and 1995 to measure the effect of insecticide application frequency on the presence and activity of general predators and parasitoids of sweetpotato whitefly in Imperial Valley, CA. This project was conducted as part of a regional three-state effort to develop action thresholds for whitefly management. Replicated plots (0.01 ha) were sprayed with a pyrethroid + organophosphate mix when densities of adult whiteflies exceeded 2.5, 5, 10, or 20 per leaf. Untreated plots served as controls. Weekly sweepnet samples were used to estimate the abundance of general predators, and leaf samples were collected to estimate the abundance of whitefly parasitoids (*Eretmocerus* and *Encarsia*).

Twelve species or groups of arthropod predators were counted. *Geocoris punctipes* was consistently the most abundant predator species, but increasing insecticide usage significantly reduced populations. In contrast, *Orius tristicolor* was the second most abundant predator and insecticide applications had little effect on populations of this species. Insecticide frequency also had little effect on *Collops* spp., *Drapetis* sp., *Spanogonicus albofaciatus*, assassin bugs (*Zelus* spp. and Sinea spp.), and *Lygus hesperus* (found to be a significant predator of pink bollworm and sweetpotato whitefly eggs); however, population densities of these species were generally low to moderate. Populations of spiders (mixed species) and *Hippodamia convergens* declined with increasing insecticide use. Population densities of *Chrysoperla* spp. were low to moderate, but abundance actually increased with greater insecticide use in both years.

The presence of *Eretmocerus* (primarily nr. *californicus*) was first detected in early to mid-July. *Encarsia* spp. were first detected in early August, but densities of these parasitoids were extremely low in both years. Populations of parasitoids and immature stages (early 4th instars and pupae) of whitefly were progressively lower in plots receiving greater frequencies of insecticide use. However, there were no significant differences in percent parasitism in any of the plots regardless of insecticide usage patterns. Percent parasitism often reached 80-95% throughout much of August for *Eretmocerus*. These results indicate that both predators and parasites may be able to exert some impact on whitefly populations even in the face of heavy insecticide pressure. Further work will be needed to quantify the effect of these natural enemies in helping to regulate whitefly populations in cotton.

Investigator's Name(s): Ru Nguyen.

Affiliation & Location: Florida Department of Agriculture, Division of Plant Industry, Gainesville, Florida.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1990 - 1995.

Importation and field release of parasites against Silverleaf Whitefly, *Bemisia argentifolii* (Bellows and Perring) in Florida from 1990-1995

For over a century *Bemisia tabaci* was considered a minor pest in Florida. In 1987 a severe outbreak occurred in nurseries on poinsettias and then on tomatoes in southern Florida. This strain of sweetpotato whitefly was referred to as *Bemisia tabaci* strain B and then later as *B. argentifolii* (Bellows and Perring). Efforts to develop a satisfactory IPM solution to the problem were initiated in 1990 by the introduction of exotic parasites into Florida. From 1990-1995, 15 parasite species were introduced into the Biological Control Quarantine Laboratory, Division of Plant Industry, Gainesville, Florida. Eight of these parasites, including *Amitus bennetti* Viggiani and Evans, *Eretmocerus* sp.(G) from Guatemala, *Eretmocerus* sp.(S) from Sudan, *Eretmocerus* sp.(HK) from Hong Kong, *Encarsia* sp.(G) from Guatemala, *Encarsia* sp.(I) from India, and *Encarsia lutea* and *Eretmocerus mundus* from Israel were approved by DPI and USDA-APHIS for field release in Florida. Approximately 305,000 *A. bennetti*; 157,800 mixed *Encarsia* sp., and *Eretmocerus* sp. from Israel, Guatemala, India, and Sudan, and 480,000 *Eretmocerus* sp. (HK), a thelytokous species from Hong Kong, were released between 1990-1995. These parasites were recovered from the fields a few weeks after release. The parasites suppressed the population of *B. argentifolii* in several locations and dispersed into sprayed areas where a large number of parasites were released. Other species have been evaluated and will be released after they are cleared from the quarantine.

Investigator's Name(s): Jean-Claude Onillon[1], Mohamed Braham[1] and Alan Kirk[2].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994 - 1995.

Preliminary results on the Efficacy of *Eretmocerus mundus* (Hyménopt.: *Aphelinidae*), in the biological control of *Bemisia tabaci* (Homopt.: *Aleyrodidae*)

As a result of systematically carried out surveys for natural enemies of *Bemisia tabaci* in Provence and the Alpes-Maritimes of southern France over the last 4 years, the Aphelinid *Eretmocerus mundus* was the most common after *Encarsia pergandiella*. After having tested the possibilities of *E. pergandiella* in the control of *Bemisia*, its positive and negative points (San Diego, January 1995), a series of experiments was started to evaluate the possibilities of *E. mundus* in the control of *Bemisia* on a crop of protected spring tomatoes.

Recently emerged *Bemisia* adults were used at the end of March 1994 to infest tomatoes at the rate of 5 adults per tomato plant with an homogenous distribution within the crop (50 adults/10 plants were released). The 120 m^2 greenhouse contained 200 tomato plants in 4 lines of 50 plants.

The first release of *Eretmocerus* was made 3 weeks after the experimental infestation of *Bemisia*. The releases numbered 6, and were made over a two-week period depending on numbers of the parasitoïds available from the laboratory rearing. The number of parasitoïds released corresponded to a ratio of 2 adult parasitoïds to 3 whitefly adults as observed on the day of the initial infestation. The sex-ratio of the parasitoïds release was 1/1. At the moment of the first release of *Eretmocerus* a sample of 8 tomato leaves showed that the WF larval population was at stages L_2-L_3.

The counting of Bemisia adults, leaf by leaf and plant by plant over a 4-week period following the introduction of the whitefly showed a constant pattern in the adult distribution.

At the beginning of May, a strong majority of final instar larvae from the first generation of *Bemisia* and immature stages of the second generation are present. Percentage parasitism by *Eretmocerus* is low (27.7%) and a few larvae parasitized by *Encarsia* were noted. The preimaginal population of *Eretmocerus* was made up of immature larvae (35.6%), prenymphs (29.9%) and nymphs (17.2%) in L_4 of *Bemisia*; the eggs of the parasitoïd are laid under all larval stages with a predominance for the L_3 stage. At the end of May, numerous larvae of the second generation of *Bemisia* are present. Percent parasitism remains low (20.3%) and the percentage of WF larvae parasitized by *Encarsia* between 10-12%. The parasite population is mainly composed of eggs (56.1%) in the L_1 and L_2 stages of the first generation of *Bemisia* and emergence holes (34.2%) in the L_4 stages of the first generation. At the beginning of June, it is larvae of the second WF generation which predominate. Percent parasitism becomes more important with 40.8% of larvae parasitized by *Eretmocerus*. Larvae parasitized by *Encarsia sp.* remain constant at about 11.1%. The parasite population consists of a majority of eggs (46.3%) in all larval stages and immature larvae (42.1%) only in the L_4 stages of the WF. At the end of June, the larval population of the WF was at the L_4 stage of the second generation. The percent parasitism by *Eretmocerus* is higher (44%), but one observes a strong increase in the percentage of WF larvae parasitized by *Encarsia sp.* (26%). The parasite population is composed of young larvae (38.6%), old larvae (17.1%), prenymphs (15.9%) and nymphs (13.8%) in the L_4 stage of *Bemisia*.

From a low release of *E. mundus* corresponding to 2 parasitoïds adults for 3 WF adults, nearly 50% parasitism was observed in the second generation of *Bemisia* which suggests a promising efficiency of this natural enemy. The next experiments will be carried out with larger numbers of natural enemy in the order of 4:1 in the expectation of obtaining satisfactory control of the first generation of *Bemisia*.

Investigator's Name(s): C. H. Pickett, and K. A. Hoelmer[1].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: August to December 1995.

Low Temperature Oviposition Rate of Aphelinids: a Technique for determining winter tolerance of Exotic Parasites for Release in Imperial Valley

The USDA-APHIS PPQ Mission, Texas Biological Control Center has over 30 species/populations of *Eretmocerus* and *Encarsia* (Aphelinidae). The ability for these parasites to survive and reproduce under winter conditions may play an important role in their permanent establishment in the desert regions of southwestern United States and their impact on silverleaf whitefly. We report on an ongoing project to measure and compare the oviposition rates of several candidate parasites at three temperatures representing winter conditions in southern California and Arizona, 45°, 55°, and 65° F (7.2° 12.7, and 18.3° C, respectively). This range of temperatures include the lowest one that parasites would be expected to oviposit in the field.

Methods

Adult parasites and a single hibiscus leaf infested with whitefly nymphs were placed in arenas made from 3.5 inch plastic petri dishes. Three adult parasites of each species/population were placed into each of three dishes for each temperature setting. Petri dishes were sealed with parafilm but were fitted with a 3/4" diameter hole in the top half, covered with a monofilament fiber for breathing (155 strands per inch). Petri dishes with leaves and parasites were placed inside an environmental chamber under controlled conditions of temperature and light. Therefore, each chamber represented one experimental unit with three subsample petri dishes for each culture of parasite being tested. The number of eggs per nine adults of each species was recorded after 60 to 72 hrs.

Due to the need for replication and a limited number of chambers (three), this study has been conducted over a six month period, beginning in August, 1995. Parasites have been reared at three different locations with similar but different rearing conditions. Most of the parasites were reared with natural and/or artificial lighting providing 14 hours of daylight. Nighttime low and daytime high temperatures averaged approximately 67° to 85° F (19.4° to 29° C). The following species/populations have been tested (accession numbers and country of origin): M95012 (*Eretmocerus* sp. Pakistan), M94056 (*Encarsia* nr. *hispida* Brazil), M92014 (*Eretmocerus* sp. Spain), M94023 (*Eretmocerus* sp. Thailand), and M94055 (*Encarsia* nr. *pergandiella* Brazil).

Results and Discussion

Pooling oviposition rates across all temperatures, no significant differences were found among tested populations (ANOVA p= 0.84; n= 2 to 9). The mean number of eggs oviposited per adult over the three day trial period varied from 0.37 to 0.93. No significant differences were found among tested species at each temperature level (7.2°, 12.7, and 18.3° C, respectively) (ANOVA p = 0.74, n = 2 to 9). The mean number of eggs oviposited at these three temperatures varied among populations from 0 to 0.65 at 7.2°C, 0.40 to 0.70 at 12.7°C, and 0.67 to 1.76 at 18.3°C. One unexpected result was the change in oviposition rate over the course of the study, despite constant rearing and experimental conditions. Initially none of the populations oviposited at 7.2°C. However the oviposition rate beginning in October increased for all tested species and at all three temperatures. They peaked in early November and appear to be decreasing. The highest number of eggs oviposited per adult increased from 0 to 1.5 at 7.2°, from 0.16 to 3.1 at 12.7°C and from 0.83 to 3.1 at 18.3°C. The reason for the change in oviposition rate is unknown. These studies will continue, increasing the number of replicates and tested populations

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: September 1994 to November 1995.

Release of Aphelinids for Control of Silverleaf Whitefly in San Joaquin Valley, California

During fall 1994 six species/populations of aphelinids reared by the Mission, Texas USDA-APHIS PPQ Biological Control Center were released at five locations in or near Bakersfield, California to establish permanent populations of new silverleaf whitefly natural enemies. Parasites were released primarily at private homes that served as year round field insectaries or refuges, free of pesticides and untimely cultivation. Home-sites were selected that contained woody perennial plants susceptible to silverleaf whitefly (hibiscus, lantana) and had home vegetable gardens with year round plantings attacked by silverleaf whitefly (okra, melons, broccoli). Releases were made so that each site received species combinations that could be separated morphologically or through genetically unique DNA patterns. A grand total of 99,500 parasite pupae were released, 9000 to 32,000 of each species/population. Three old world species/populations of *Eretmocerus*, one old world strain of *Encarsia* and two new world species of *Eretmocerus* were released onto hibiscus, lantana, or one of several herbaceous plants. During fall 1995, 28 species/populations of aphelinids, 26 reared by the above facility and two reared by the California Department of Food & Agriculture, were released at 20, mostly home-site, locations in Kern and Tulare Counties. A grand total of 183,714 pupae were released, 600 to 34,500 of each species/population. All released parasites were of old world origin. Post release monitoring has included recovery and identification of released parasites and whitefly density estimates. Emerged adult parasites were identified using traditional morphological techniques and new molecular biology technology, e.g. RAPD-PCR (randomly amplified polymorphic DNA - polymerase chain reaction). Two of the six species/populations released in 1994 were recovered as late as August 1995 at one of two release sites in Bakersfield, both private homes. At one of these sites all recovered male *Eretmocerus* were identified as an exotic parasite with accession number M93005 collected from Thirumala, India. The second recovered parasite, *Eretmocerus mundus* (M92014), was collected from Murcia, Spain. This is the first known report for year round establishment of a *Bemisia argentifolii* parasite in California.

Investigator's Name(s): George W. Pittarelli[1], J. George Buta[2], Ray F. Severson[3], and Stephen F. Nottingham[3].

Affiliation & Location: [1]Soybean and Alfalfa Research Laboratory; [2]Horticultural Crops Quality Research Laboratory Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD 20705-2350; [3]Phytochemical Research Unit, Richard B. Russell Agricultural Research Center, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 5677, Athens GA 30613.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994 - 1995.

A Novel and Rapid Bioassay to Screen *Nicotiana* Species for Activity Against the Adult Silverleaf Whitefly *Bemisia Argentifolli* N.

The silverleaf whitefly (SLWF), *Bemisia argentifolli* N. (formerly *Bemisia tabaci* strain B) has become a serious economic pest in recent years in the field and in the greenhouse. In order to accelerate the screening of *Nicotiana* species for use as sources of biorational insecticides we have developed a novel, economical and rapid bioassay using the whitefly. It involves the immobilization of adult SLWF on yellow sticky strips before spraying them with the test extracts. Mortality is scored after 2 hours.

Investigator's Name(s): George W. Pittarelli[1], J. George Buta[2], Orestes t. Chortyk[3] and Susan Wilson[3]

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994 - 1995.

Increased Production of Biopesticides from Interspecific Hybridization of *Nicotiana* Species

Sucrose esters extracted from leaf surfaces of *Nicotiana* species have been found to be effective, environmentally-safe biopesticide against SLWF whitefly *Bemisia argentifolli* N., aphids and other plant pests. However, the quantities of these compounds produced by the plants are relatively small. To increase the quantities of these compounds a breeding program is being carried out at Beltsville, MD. The sesquidiploid 4N (*N. gossei* X FL 17) was selected for this investigation. This sesquidiploid is susceptible to SLWF but can be easily back-crossed with diploid or tetraploid *N. gossei* genomes highly resistance to SLWF, aphids and other insect species. These selections produced are more suitable to our climatic conditions with cigar-wrapper plant morphology of 1.50 to 2 meters average height with larger leaves and suitable for mechanical harvesting.

Investigator's Name(s): George W. Pittarelli[1], J. George Buta[2], and Orestes T. Chortyk[3], Susan Wilson[3], and Azhar Hossain[1].

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1994 - 1995.

The Use of Chromosome Amplification to Increase the Quantity of Biopesticide Production from *Nicotiana* Species

Sucrose esters isolated from leaf surfaces of some *Nicotiana* species have been found to act as effective, environmentally safe biopesticides against soft-bodied arthropod plant pests; however, the quantity of these compounds produced by the plants are relatively small. Therefore, an attempt to increase the quantity of these compounds produced by trichomes of various *Nicotiana* species by chromosome amplification was investigated. Increased insecticidal activity was found in induced polyploid *N. gossei* and *N. glutinosa* plants against whiteflies and aphids.

Investigator's Name(s): William Roltsch[1] and Charles Pickett[2]

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Research & Implementation Area: Section D: Biological Control

Dates Covered by the Report: October 1994 to October 1995.

Evalution of Refuges and New Refuge Plants for Support of Silverleaf Whitefly Natural Enemies

For a second full year, silverleaf whitefly natural enemy refuges were evaluated in the Imperial Valley. Plots consisted of two rows of refuge plants alternating with 18 rows of cotton or 9 rows of melon. Refuge plantings occurred twice each year at each field site; the first in early March (interplanted sunflower, collard, and roselle [*Hibiscus sabdariffa*] that was transplanted in May) and a second in late September (interplanted sunflower and collard). Two refuge plots (1-2 acres each) and corresponding check sites were evaluated at the USDA field station in Brawley. In addition, a refuge plot consisting of refuge strips and cantaloupe (5 acres), and a remote check site were present at a second farm site (organic) in southern Imperial County.

Parasitism of whitefly by *Eretmocerus* spp. on spring cantaloupe was considerably greater on refuge and control plots during the spring of 1995 at the one USDA Station than reported the previous year. Although data analysis is pending, parasitism was commonly over 30% on cantaloupe in the refuge plot. Rubidium label studies (see abstract by Andrew Corbett, U.C. Davis), determined that a large percentage of the *Eretmocerus* parasites in cantaloupe adjacent to refuge plantings originated from the natural enemy refuge plants. Many parasites also moved into the adjacent cotton plot as well. Native *Encarsia* spp. that were common on the refuge plant species (mostly collard) did not disperse extensively into adjacent cantaloupe and cotton. Cantaloupe in the second field station plot did not establish well due to poor germination associated with cool temperatures, and a late cotton stand was established only after planting seed a second time. Label studies showed a similar pattern in this site as well.

Evaluations are currently underway to identify perennial plant species that can be used as natural enemy refuge plants. Some of these plants are native species in the desert southwest, including *Justicia and Ruellia* spp. (Acanthaceae), *Datura* spp.(Solanaceae), *Cucurbita* spp.(Cucurbitaceae), Lavatera and Anisodonta spp. (Malvaceae). Other species include eggplant, holly hock, "rue" *Ruta graveoleus*, and *Lantana camara*. Perennial plants are being sought that can cope with widely varying soil conditions and watering regimes (preferably low), and ability to retain leaves through the cool winter months. Few plants appear to have these qualities along with being attractive insectary plants. Preliminary findings pertaining to *Justica californica* (chuparosa) look encouraging relative to the above stated qualities that are desired of a natural enemy refuge plant. Of particular note, is that this desert plant species appears to be capable of tolerating a wide range of watering regimes, and is expected to require far less water than many plants. Although establishment of this and other perennials is a lengthy process, permanent hedge rows could be relative easily established and maintained.

Several annual plant species in addition to sunflower, and collard have been evaluated for their usefulness in cool season refuges in particular. Soybean was found to have a very short growth period during the fall and winter, was severely attacked by whitefly, and appears to have little potential usefulness in the Imperial Valley as a natural enemy refuge plant. Chickpea is a very poor host of whitefly in Imperial Valley and therefore is of little use. Lab lab (a third legume spp.) is still being evaluated but is expected to be of only limited potential value as an insectary plant.

We intend to rank plants according to how they can be expected to perform under varying whitefly densities. That is, some plant species may only play a role in harboring sufficient numbers of parasitized whitefly in geographic regions where high whitefly densities occur, whereas other plant species may "overload" with whitefly under such conditions, yet perform well in areas where whitefly densities are low to moderate.

Investigator's Name(s): Colmar-A. Serra, Manual Ortíz, José B. Nuñez, Andrea Schulz and Pedro F. Benoit.

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Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995 - 96.

Potential of Entomophagous fungi to Control Whiteflies on Dominican Vegetable and Ornamental Crops

Studies on the efficiency of different imported and native strains of entomopathogenic fungi (EF) and commercial mycoinsecticides were undertaken in order to evaluate their prospects as a component of IPM management programs in tomatoes, ornamentals and other crops heavily affected by whiteflies (*Bemisia tabaci* and/or *Trialeurodes vaporariorum*). Natural occurring fungi (*Paecilomyces fumoso-roseus* and *Verticillium lecanii*) showed a limited efficiency on *T. vaporariorum* depending on the climatic factors (i.e., altitude ≥400 m.a.s.l., colder season), as well as the crop and its pest and disease management program (i.e., fungicides). According to differences in the optimal temperature for their development, *V. lecanii* reached high mortality rates in non-sprayed ornamental and vegetable crops in the Constanza valley (≥1000 m.a.s.l.), where *T. vaporariorum* presents very serious problems due to their exposure to an excessive high resistance-selection pressure. In the Jarabacoa valley, center of the ornamental production at 500 m.a.s.l., both main target species co-exist, dominating *T. vaporariorum*. Naturally occurring *P. fumoso-roseus* showed an efficiency of <50% reducing mainly *T. vaporariorum* in Gerbera, Aster and other ornamental plants. However, in lowlands under rather hot and dry climate conditions (500-1000 mm rain/year, 0 temperatures 24-28°C), the main habitat of *B. tabaci*, practically no natural infection with EF was found on any whiteflies, except of single fields of *Momordica charantium* and *Solanum melongena* in La Vega with an untypical *T. vaporariorum* infestation, where *P. fumoso-roseus* reached medium to high levels of biocontrol.

In laboratory tests, strains of *P. fumoso-roseus*, *V. lecanii*, *Beauveria bassiana*, and *Metarhizium anisopliae* originating from Richard Hall, NIHERST, Trinidad & Tobago (TRI) were compared to locally collected strains of *V. lecanii* and *P. fumoso-roseus* as well as to commercial products such as PreFeRal® (*P. fum.*, W.R. Grace & Co., Conn., MD, USA), Mycotal® (*V. lec.*, Koppert BV, Berkel en Rodenrijs, the Netherlands), Vertisol® (*V. lec.*), and Vektor® (*Entomophthora virulenta*, both: Laverlam, Cali, Colombia). For the comparisons and for the determination of the LC_{50} values, leaf disks were infested with third stage larvae and dipped into conidia suspensions (10^5-10^9 spores/ml). After drying, the leaf disks were fixed on a layer of Calcium sulphate on a slide and incubated in Petri dishes for up to 7 days. Among the tested non-commercial strains, under laboratory conditions with average temperatures of 27(23-32)°C, *P. fum.* (TRI) gave the most consistent results concerning the infectiousness and spore viability followed by some native *P. fum.* strains, *V. lec.* (TRI) and native strains.

Under semi-field conditions in the cold season and at 500 m.a.s.l., commercial mycoinsecticides (*V. lec.* and *P. fum.*) increased whitefly biocontrol in ornamental plantings. Good perspectives are expected for the use of *V. lecanii* for whitefly control in mountain valleys of the Cordillera Central. Not concluded field trials still might have to show, whether in the hot and dry lowlands, the main processing-tomato growing area, the implementation of mycoinsecticides makes sense, specially during the hot but humid summer month.

Investigator's Name(s): Colmar-A. Serra, Manual Ortíz, José B. Nuñez and Pedro F. Benoit.

Affiliation & Location: Proyecto 'Mosca Blanca,' Departamento de Agronomía, Instituto Superior de Agricultura (ISA), Apartado 166, Santiago de los Caballeros, Dominican Republic.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Survey of Indigenous Natural Enemies of Whiteflies in the Dominican Republic

In order to enhance biocontrol as a component of IPM of whiteflies, specially *Bemisia tabaci* and *Trialeurodes vaporariorum*, a survey was carried out covering the main vegetable-growing areas of the D.R. during the summer of 1995, the so-called 'host-crop free period,' and afterwards. Plant material was sampled from known wild and cultivated whitefly-host plants, evaluated for larvae, puparia and pupal cases of distinct whitefly species and kept until the emergence of adult whiteflies (≥12 spp.) and parasitoids (Hymenoptera-Aphelinidae: *Encarsia* spp. (≥5), *Eretmocerus* sp. (≥1); -Platygasteridae, *Amitus* sp.). Predatory mirid bugs, coccinellids, spiders and others were recorded as well as the incidence of naturally occurring entomophagous fungi (Hyphomycetes-Moniales: *Paecilomyces fumoso-roseus* and *Verticillium lecanii*).

The definitive taxonomic classification of several whitefly parasitoids has to be concluded, yet (J. Wooley, M. Ciomperlik in Mission Biological Control Center, Texas, and G. Evans, Gainesville, University of Florida). In addition to the most distributed and dominant *Encarsia* sp. (*parvella* group), and an *Enc.* sp. (*luteola* group), single *Encarsia* wasps are likely to belong to non-described species. The presence of *Enc. pergandiella* and *Enc. meritoria.* (=?*hispida*) and *Eretmocerus* sp. nr. *californicus* has been confirmed. *Enc. nigricephala* plays a limited role in the biocontrol of *Aleurotrachelus trachoides* in different *Capisicum* crops, *Ipomoea batatas* and wild vines. The by far most important parasitoid of *T. vaporariorum* with parasitism levels of up to 95% in unsprayed plants is *Amitus* sp. (*A. fuscipennis*?). Biotests with the most common endemic *Encarsia* spp. are being carried out and will serve as a base for planned comparisons with introduced biotypes to import from Mission, TX, in order to start mass rearing and liberation of the most promising species or biotype(s).

Predators of whiteflies seem to play an important role in biocontrol only locally. Only mirids (*Cytopeltis tenuis, C. modestus* and others) were found in high densities in presence of heavy *B. tabaci* infestation in tomatoes, tobacco, cucurbits, and other crops and weeds. Coccinellids (*Delphastus* spp., *Hippodamia convergens, Cycloneda* sp. and others) have been recorded in many places, but mainly in low densities. Spiders of different genera occasionally could occur in important numbers in presence of high whitefly densities, specially of *T. vaporariorum.*

Naturally occurring entomophagous fungi attacking *B. tabaci* do not play any role in processing-tomato growing areas of the dry northwestern and southwestern lowlands for the moment. In valleys of the Cordillera Central at altitudes over 400 m.a.s.l. and during the colder seasons, *P. fumoso-roseus* and at even higher altitudes *V. lecanii* show a high incidence in many ornamentals, weeds and crops without heavy pesticide-spraying programmes. Studies are being carried out to determine their potential for whitefly biocontrol.

Investigator's Name(s): Alvin M. Simmons and Matthew A. Ciomperlik.

Affiliation & Location: USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC and USDA-APHIS-PPQ, Mission Biological Control Center, Mission, TX.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: August - November 1995.

Exotic Parasitoid of *Bemisia argentifolii* in South Carolina

Eretmocerus sp. nr. *mundus*, an exotic parasitoid of *Bemisia argentifolii*, was released and monitored in coastal South Carolina. The parasitoid was originally collected from Murcia, Spain, and is maintained in a colony at the USDA Mission Biological Control Center in Texas. Releases were made at three sites in Charleston County, South Carolina: two farms of a commercial grower, and at the U.S. Vegetable Laboratory research farm (USVL). At the USVL research farm, releases were made in tomato and collard. On the commercial farms, parasitoid releases were made in cantaloupe, collard, eggplant, and tomato. No post-plant pesticide was used at the USVL research farm release site. However, to produce marketable vegetables on the commercial farms, post-emergence pesticides were used as needed. Populations of adult whiteflies were low in the cantaloupe, collard and tomato, but were relatively high in the eggplant. On eggplant, whitefly nymphs reached 1 per cm^2 in late September and the density increased to ca. 7 nymphs per cm^2 by late November. Conversely, there were only a few nymphs per whole leaf in the other crops throughout the study.

Seven releases were made from late August to early November, generally at 2-week intervals. Approximately 60,000 parasitoids were released. Releases were not made throughout each field but within concentrated areas to enhance parasitoid mating and thus, increase the likelihood of its establishment. One week after the second release and one week after each subsequent release, sticky cards were placed in the fields for one week. Any released parasitoids should have died by the time sticky traps were placed in the fields. Thus, any *E.* sp. nr. *mundus* collected on the sticky cards would have been from emergence from locally parasitized whiteflies. Sticky trap samples were stored in a freezer for later processing. A few *E.* sp. nr. *mundus* were found on sticky cards and recovered from leaf samples. Collards are still in fields at two locations, and whiteflies are still on the leaves. Sticky cards sampling will continue on this crop into early 1996 to determine if the exotic *E.* sp. nr. *mundus* has become established.

Investigator's Name(s): Gregory S. Simmons[1], Kim Hoelmer[2], Stefan Jaronski[3] and Jeff Lord[3].

Affiliation & Location: USDA-APHIS-PPQ, Western Region[1] & Phoenix Plant Methods Center[2], Brawley, CA & Mycotech Corp.[3], Butte, MT.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 to December 1995.

Effect of *Beauveria bassiana* GHA (Mycotrol WP) on Parasitoids of *Bemisia* in Spring Melons

Parasitoids and entomopathogenic fungi each have an important role in biological control and IPM of whiteflies. Since many parasitoids are susceptible to infection by pathogens when topically applied, this study was conducted in the Imperial Valley, CA, to investigate the compatibility of field applications of *Beauveria bassiana* (formulated as Mycotrol WP) with augmentative releases of a non-indigenous parastoid of *Bemisia*, *Eretmocerus* sp. M92019 (ex Padappai, India).

Plots 0.75 acre in size located within two commercial canteloupe (Elder 8) and mixed melon fields (Sumac 12) were treated with weekly releases of the parasitoid. Crop development at the Sumac 12 site was more advanced and higher populations of whiteflies were present than at the Elder 8 site. Releases were begun 21 March (Sumac 12) and 28 April (Elder 8) and continued until 19 May. An estimated 40K parasitoid pupae were released at the Elder 8 site, and 120K at the Sumac 12 site. At each site paired plots, 5 rows by 40 row-feet, located within the release plots were also treated with Mycotrol WP applied at 1 lb/acre and a carrier control (Silwet L-77, 0.04%) using an airblast backpack sprayer. Each site was sprayed on 19, 24 and 31 May.

Parasitoids were sampled from each site prior to the first *Beauveria* application, and again at 12 and 28 days after the first treatment was applied. Fourth-instar whiteflies were recorded as appearing unparasitized or obviously parasitized. Each group was further categorized as live or dead, and whether or not fungal infection was apparent by presence of hyphae or red pigment, a secondary metabolite of the *Beauveria* strain.

The post-treatment mean numbers of whitefly nymphs were significantly lower in the Mycotrol plots. Mean numbers of *Eretmocerus* were lower in the Mycotrol plots than in the carrier-control or parasitoid-only plots in both post-treatment samples at the Sumac site, and on the second sample date at the Elder site, but these differences were not statistically significant. Percentage parasitism of fourth instars was likewise not significantly different among treatments. Infection of unemerged larval and pupal *Eretmocerus* by *Beauveria* was detectable by lab examination of the samples, however. The proportion of *Bemisia* parasitized by *Eretmocerus* at the Elder 8 site that were infected with *Beauveria* was 31% at day 12 and declined to 2.3% at day 28, while at the Sumac 12 site the proportion of infected parasitoids at day 12 was 8.4%, increasing to 53% at day 28. Mortality on this date was high in all treatments at this site and may have been influenced by sample storage. We also examined all parasitoids that died without visible signs of *Beauveria* infection. This proportion was not significantly different between the treatments, suggesting that there were no significant lethal effects of *Beauveria* that occurred without visible manifestations.

We conclude that 1) parasitoids and whiteflies were less abundant in *Beauveria*-treated plots; 2) *Eretmocerus* can be infected by *Beauveria bassiana* GHA applied under field conditions; 3) a reduction in parasitism could occur from the death of potential whitefly hosts; 4) large percentages of *Eretmocerus* survived the treatment with fungus; and 5) overall percentage parasitism was not significantly reduced by *Beauveria* applications.

Investigator's Name(s): Gregory S. Simmons[1], Kim Hoelmer[2], Robert Staten[3], Theodore Boratynski[4].

Affiliation & Location: USDA-APHIS, PPQ, Western Region, Brawley[1] and El Centro[4], USDA-APHIS, Phoenix Plant Methods Center, Brawley, CA[2] & Phoenix, AZ[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 to December 1995.

Seasonal Inoculations in Spring Melons with Parasitoids of *Bemisia*

The primary goal of this project was to increase biological control of the silverleaf whitefly (SLW), *Bemisia argentifolii*, in spring melons by rearing and releasing several species of SLW parasites. Native parasites of SLW (*Eretmocerus* sp. & *Encarsia* spp.) are not effective against SLW on spring melons and levels of parasitism are generally low on these crops in the Imperial Valley of California. It is in the spring melon crop where SLW populations first start to rapidly increase. If a more effective parasite against SLW infesting spring melons was introduced in these agroecosystems, it should result in lower whitefly populations on successive summer crops and lead to higher populations of parasites at the beginning of the next planting cycle.

Parent material from the USDA, APHIS, PPQ, Mission Biological Control Center in Mission, TX, was introduced into the Imperial Valley Greenhouse Insectary for a one-generation increase rearing. Two exotic species of *Eretmocerus* were reared for release in 1995: *Eretmocerus* sp. M92019 (ex Padappai, India) and *Eretmocerus* sp. M92014 (ex Murcia, Spain). Releases were made into replicated 0.2 ha. plots of untreated and imidacloprid (Admire™) treated cantaloupes. There was a total of 10 releases of each species. Weekly releases of parasites began on 21 March and continued until 19 May. A total of 256,000 and 210,000 parasites per ha. of *Eretmocerus* spp. M92019 and M92014 respectively were released.

Releases in untreated melons resulted in increased parasitism of SLW relative to no-release plots. The highest mean levels of parasitism achieved were 40% and 27% in release plots of *Eretmocerus* spp. M92019 and M92014 respectively. These levels of parasitism were significantly higher than the highest level of 7% parasitism by native parasites observed in the no-release control plots. Parasitism in individual fields was as high as 60% indicating that higher levels of parasitism are possible. SLW levels were lower in release plots than in no-release plots. The highest level of SLW was 2.2 pupae per cm^2 in the no-release plot versus 1.8 and 0.9 pupae per cm^2 in release plots of M92019 and M92014 respectively. SLW levels were reduced by 59% in M92014 release plots and were significantly lower than SLW levels in the no-release control plots.

Releases of parasites into imidacloprid-treated cantaloupes also resulted in increased parasitism and reduced SLW levels. The highest mean levels of parasitism achieved were 43% and 16% in release plots of *Eretmocerus* spp. M92014 and M92019 respectively. These levels were not significantly different from the high of 7% parasitism observed in the no-release control plots. There was a trend of lower SLW levels in release plots relative to no-release plots. The highest level of SLW was 0.7 pupae per cm^2 in the no-release plot versus 0.4 and 0.3 pupae per cm^2 in release plots of M92014 and M92019 respectively. These results from the imidacloprid-treated cantaloupes, while not significantly different, suggest that it is possible to combine parasitoid release with imidacloprid treatment and this combination may be more efficacious than the sole use of imidacloprid.

Investigator's Name(s): Michael T. Smith.

Affiliation & Location: USDA, ARS, MSA, Southern Insect Management Laboratory, Stoneville, MS.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Efficacy of Parasitoid Species Against Silverleaf Whitefly

This research program is focused on the evaluation of exotic parasitoid species from areas of *Bemisia tabaci* origin for use in control of *Bemisia argentifolii* in very select geographic areas, on high value cash crops, and under specific agronomic or management systems in the United States (Imperial Valley in California, Rio Grande Valley in Texas, and Florida; field crops, vegetables, ornamentals, etc.; field crops vs greenhouses), and identification of key parasitoid efficacy parameters.

The behavioral performance of two geographically distinct populations of *Encarsia formosa* were evaluated under a range of different temperature regimes (16°C, 21°C, 26°C, and 31°C), which included temperatures found in their geographic areas of origin. The parasitoid populations originated from Greece (Greece strain-M92017) and Egypt (Nile strain-M92030). Behaviors evaluated included walking/drumming, drumming, stinging, feeding, preening, standing and walking off the leaf. Results from these studies (average time, average percent time, frequency of behaviors and percent parasitoids performing selected behaviors) showed that temperature strongly influences parasitoid behaviors, with the Greece strain adapted to a cooler climate (21°C), and the Nile strain adapted to a warmer climate (26°C-31°C). These data correlate well with the climatic conditions which exist in the geographic regions of origin of each *E. formosa* strain. When coupled with our previously reported evaluation of life history parameters, these results show the existence of a climatic-species adaptation in *E. formosa*, which leads to the conclusion that these 'ecotypes' are differentially adapted to precise ecological conditions. There data also indicate that walking, drumming and stinging are optimal at the preferred temperature(s), and may be among the more discriminating behavioral parameters which are indicative of parasitoid efficacy.

Research was also initiated to determine the effect of host plant on parasitoid efficacy. Four stains of *E. formosa* (Greece strain, Nile strain, Beltsville strain and the commercial strain) and seven host plant species in five plant families were included in these tests. Results at this time are preliminary and will be reported at a later date.

Investigator's Name(s): Michael T. Smith[1] , Miriam Allred[2] and Matthew Ciomperlik[3].

Affiliation & Location: USDA-ARS-MSA, Southern Insect Management Laboratory, Stoneville, MS [1]; USDA-APHIS-PPQ, Jackson, MS[2]; and USDA-APHIS-PPQ, Mission Biological Control Laboratory, Mission, TX[3].

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Identification of the Whitefly and Associated Parasitoid Species in Mississippi

In concert with parasitoid evaluations, and as a prerequisite to subsequent field evaluation and release programs, a survey of the whitefly and associated parasitoid species in Mississippi was initiated in 1995. The objectives of this research are to survey as wide a geographic area of the state, as wide a host plant range, and as wide a variety of agronomic/management systems as possible. Leaves infested with late instar whitefly nymphs were sampled. Sampling was coordinated between ARS, APHIS and the Mississippi State University Agricultural Extension Service (county agents). Whitefly adults and pupal casings, as well as adult parasitoids were preserved for identification.

To date, whiteflies have been collected from 35 host plant species in 18 counties. Host plants include 2 field crops (cotton and soybean), 15 vegetable species, 11 ornamental species, 3 herb species, as well as 2 weed species. Although identifications are only tentative, whitefly species appear to include 3-4 species: bandedwinged whitefly [*Trialeurodes abutilonea* (Haldeman)], greenhouse whitefly [*Trialeurodes vaporariorum* (Westwood)], and silverleaf whitefly (*Bemisia argentifolii* Bellows and Perring) and/or sweetpotato whitefly [*Bemisia tabaci* (Gennadius)]. Parasitoids have been collected from whiteflies on 21 plant species in ca. 30% of the samples collected. Verification of whitefly identifications, parasitoid identifications, and continuation of this survey will be performed during 1996.

Investigator's Name(s): Don C. Vacek, Raul A. Ruiz, and Lloyd E. Wendel.

Affiliation & Location: USDA-APHIS-PPQ, Mission Biological Control Center, Mission, TX.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

RAPD-PCR Identification of Natural Enemies of SPWF

Genetic fingerprinting with randomly amplified polymorphic DNA (RAPD) provides a rapid and reliable method for insuring quality control of mass-reared biological control agents and identifying undescribed populations of potential biological control agents. The integration of molecular genetic techniques into quarantine importation and culture of exotic natural enemies has enhanced the implementation of biological control of *Bemisia tabaci,* biotype B (SPWF). The Mission Biological Control Center (MBCC) serves as the primary quarantine for USDA in the importation of natural enemies of SPWF. Voucher specimens of the natural enemies imported and cultured in the quarantine laboratory are provided to both systematists and the MBCC Genetics Diagnostics Laboratory. While systematic determinations are in progress, specimens are rapidly and reliably identified with genetic fingerprints.

The *Encarsia* populations will most likely be classified as the following species: *E. formosa*, *E. transvena*, *E.* nr. *strenua*, *E. pergandiella*, *E.* nr. *pergandiella,* and *Encarsia* sp.. A total of 50 *Encarsia* populations from 17 countries (Africa, Argentina, Brazil, Cyprus, Dominican Republic, Egypt, Greece, India, Israel, Italy, Malaysia, Nepal, Philippines, Spain, Taiwan, Thailand, and U.S.A.) were divided into 18 RAPD pattern groups which generally followed species designations where available. The *Encarsia* patterns were distributed uniquely as follows: U.S.A. (EN 9, 12), U.S.A. and Italy (EN 8), India (EN 1), Southeast Asia (EN 3, 4, 6, 11), Dominican Republic (EN 18), Mediterranean (EN 7, 10, 13, 14), and South America (EN 15, 16, 17). Two patterns were widely distributed (EN 2, 5).

A total of 41 *Eretmocerus* populations (representing *Eretmocerus* spp. and several undescribed species) from 10 countries (Egypt, India, Israel, Italy, Pakistan, Spain, Taiwan, Thailand, United Arab Emirate, and U.S.A.) were divided into 12 RAPD pattern groups. The *Eretmocerus* patterns were distributed uniquely as follows: India (ERET 2), United Arab Emirate (ERET 12), Pakistan (ERET 10), U.S.A. (ERET 4, 5, 6, 7), and Southeast Asia (ERET 3, 8, 9, 11). One pattern was widespread (ERET 1). Genetic fingerprinting with RAPD complements systematic determinations and is an effective way to identify insects for delivery of a biological control program.

Investigator's Name(s): Fernando E. Vega[1], Michael R. McGuire[1], Mark A. Jackson[2], and Sophie Cliquet[2].

Affiliation & Location: USDA, ARS, National Center for Agricultural Utilization Research (NCAUR), [1]Bioactive Agents Research Unit and [2]Fermentation Biochemistry Research Unit, 1815 N. University St., Peoria, IL 61604.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: May - December 1995.

Formulations of the fungal entomopathogen *Paecilomyces fumosoroseus*

The Bioactive Agents Research Unit and the Fermentation Biochemistry Research Unit at the National Center for Agricultural Utilization Research have started a collaborative project aimed at developing a *Paecilomyces fumosoroseus* (PFR) formulation. Using a liquid medium which yields desiccation tolerant PFR blastospores, our main focus will be to use surplus agricultural commodities as the matrix for the formulations. Among the materials tested to date are corn starch, modified corn flour, trehalose, sucrose, dextran, gums (carrageenan and xanthan), and oil. Different percentages of these materials were mixed directly with the liquid medium and freeze dried in 5 ml serum vials using a Dura-Top MP Freeze-Dryer with an automatic-eutectic drying program. This program determines the eutectic point of a sample and sets the primary and secondary drying conditions based on this information with an ending shelf temperature of 4°C. All vials were stored at 4°C.

Formulations were assessed for blastospore survival based on a comparison of blastospore numbers prior to freeze drying with percentage recovery at different periods of time after freeze drying. Determinations of cfu's were made using the standard plate count method

Our results indicate that the blastospores are tolerant to desiccation as indicated by survival following lyophilization. For most formulations, blastospore survival decreased with increased sampling time. One notable exception are the formulations containing Buffalo corn starch, modified corn flour, sucrose, and Mazola oil. Blastospore survival was higher in these formulations 60 days after initiation than in the control, which consisted of freeze-dried PFR medium.

Once a formulation with satisfactory shelf-life characteristics has been identified (e.g., survival of a high inoculum percentage for extended periods of time at either room temperature or 4°C), it will be tested against immature stages of the silverleaf whitefly [*Bemisia argentifolii* (Bellows & Perring)] maintained in laboratory colonies. A computer controlled spraying apparatus (Burkard Manufacturing Co. Ltd., England) will be used to apply the different formulations onto leaves containing a predetermined number of known whitefly instars. The materials contained within the formulation will be tested alone and in combination to assess whether they cause any mortality on their own. In addition, scanning electron microscopy will be used to assess the time from spraying until germ tube initiation; the number of blastospores attached to the insect will also be determined.

Investigator's Name(s): Claire Vidal[1,2], Lawrence A. Lacey[1] and Jacques Fargues[2].

Affiliation & Location: [1]USDA-ARS, European Biological Control Laboratory, Montpellier, France and [2]Unité de Recherches en Lutte Biologique, INRA Montpellier, Campus International de Baillarguet, 34982 Montferrier-sur-Lez, France.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: 1995.

Intraspecific variability of *Paecilomyces fumosoroseus*: vegetative growth as a function of temperature

Under certain conditions, some of the most effective naturally occurring control agents of *Bemisia* are entomopathogenic fungi. The most commonly observed fungal pathogens of *Bemisia* and other whiteflies are *Paecilomyces fumosoroseus, Verticillium lecanii* and *Aschersonia* species. The most spectacular natural epizootics in *B. tabaci* populations have been caused by *P. fumosoroseus*. A prerequisite to efficacious performance of the fungus will be normal germination and growth under the environmental conditions where the fungus will be employed. Our study was designed to measure the growth rates of several strains of *P. fumosoroseus* originating from a variety of geographic locations and environmental settings. The different strains were isolated from various insect hosts (*B. tabaci*, principally, and some species of Lepidoptera) in Pakistan, Nepal, India, Cuba, southern U.S. and Europe.

Thirty-nine isolates of *P. fumosoroseus* were grown on artificial medium at 11 temperatures between 8 and 40°C to determine growth rates and thermal tolerance. Radial growth of surface colonies fit a linear model where the slope corresponds to the growth rate. Optimal growth rates were observed at 20 to 30°C, and ranged from 3.46 to 5.15 mm/day. The highest temperatures (30-40°C) were more limiting than the lowest ones (8-11°C). The results showed an intraspecific variability partially related to the microclimate of the fungal biotopes. Most isolates originating from Europe (temperate climate) exhibited a relatively narrow temperature related growth range (11-30°C) with optimal growth at 20 or 25°C. The temperature range for the isolates originating from the southern U.S. (both humid and dry subtropical climates) and from W. Asia (humid tropical climate) was broader (8-32°C) with optimal growth at 25 or 28°C, but the growth rate remained at a high level at 32°C for the Indian isolates (monsoon climate), only. The strains from Nepal formed the only homogenous group relative to cumulative mortality (83-92%) and growth rate (4.09-4.62 mm/day). These strains were isolated from a very small area (10 m diam.) compared to the Pakistan group (10 km diam.) or even to the Indian one (1 km diam.), where we found a higher diversity for infectivity and temperature tolerance. For optimal performance in the field, the thermal requirements of isolates should be matched to the microhabitats of the target insect.

Investigator's Name(s): S. Wraight[1], R. Carruthers[1], C. Bradley[2], and S. Jaronski[2].

Affiliation & Location: [1]USDA-ARS Subtropical Agricultural Research Laboratory (SARL), Weslaco, TX, and [2] Mycotech Corporation, Butte, MT.

Research & Implementation Area: Section D: Biological Control.

Dates Covered by the Report: January 1995 - December 1995.

Efficacy of *Beauveria bassiana* Against Silverleaf Whitefly on Field Crops in South Texas

The Cooperative Research and Development Agreement (CRADA) between Mycotech Corporation and the USDA-ARS-SARL Biological Control of Pests Research Unit (SARL-BCPRU) was renewed in early 1995, and an intensive program of laboratory and field research on development of entomopathogenic fungi for biological control of *Bemisia* whiteflies is continuing. In January 1995 the *Beauveria bassiana* based mycoinsecticide codeveloped by Mycotech and SARL-BCPRU trade named Mycotrol® was granted U.S. EPA registration, and 1995 field work focused on evaluations of different formulations of this material and testing of various application technologies.

In a test initiated in April in cantaloupe, efficacy of weekly applications made by tractor driven air-assist and high-pressure hydraulic sprayers was compared to efficacy of applications made with the highly effective portable air-assist sprayer used previously (see 1994 report). A wettable powder formulation of Mycotrol* was initially applied at the rate of 0.5 lb per treated acre (equivalent to 1×10^{13} conidia per treated acre); however, when it became evident that whitefly populations were increasing to record outbreak levels across the Rio Grande Valley, this rate was increased to 1 lb per treated acre. Despite these adjustments, levels of control achieved after a total of five applications were substantially lower than achieved in 1994. Sampling after 21 days revealed preimaginal whitefly population reductions of only 66.7, 26.3, and 20.1% in the plots treated with the portable air-assist versus tractor driven air-assist and hydraulic sprayers, respectively. Investigations revealed that the efficacy was directly related to spray coverage. Mean numbers of spores deposited on coverslips affixed to the lower surfaces of the melon leaves sprayed with the three respective sprayers were 1244, 480, and 196 per mm^2.

During the summer of 1995, studies were initiated to improve spray coverage through modification of spray nozzle configuration and orientation. These studies identified nozzle spacing and distance from the target as important factors. Increasing spray rates in banded applications (up to 4×10^{13} conidia per treated acre) when plants were small was identified as another highly effective way to increase rates of spore deposition. During the fall 1995 season applications were made to three fields of cucumbers using experimental air-blast and high pressure hydraulic sprayers with nozzles spaced 8-10 inches apart, operated 4-5 inches above the ground (at the top of the cucumber crop canopy), and oriented at a 30-45° angle. In each of the test fields, four to five banded applications of Mycotrol-WP made at 7-day intervals at rates of $2\text{-}4 \times 10^{13}$ conidia per treated acre reduced populations of whitefly nymphs by 60-75%. These banded application rates translated to an average of approximately 1.5×10^{13} conidia per acre of planted ground.

In other cucumber tests with the high pressure hydraulic sprayer (400 psi), efficacy of an experimental oil formulation of Mycotrol against preimaginal whiteflies was equal to the wettable powder. Both Mycotrol formulations also exhibited efficacy against whitefly nymphs equal to a low rate of the pyrethroid Bifenthrin (as Capture® 2 EC*, 2.6 oz. per acre). Comparisons to higher rates of Bifenthrin and other synthetic chemical insecticides are planned for 1996, and evaluations of chemical insecticide-Mycotrol combinations and rotations are also in progress.

* Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

TABLE D. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Yr. 4: Determine interactions among SPW, host plants and natural enemies.			
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies.	Yr. 4: Continue evaluation of most promising methods.			
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Yr. 4: Conduct host range tests; rear, release promising natural enemies.			
D.4 Determine natural enemy host selection processes and mechanisms.	Yr. 4: Determine potential of implementing host foraging mechanisms in SPW population management.			
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Yr. 4: Develop mass propagation and release procedures for selected species.			
D.6 Determine effects of pathogens on regulating SPW populations.	Yr. 4: Monitor dispersal and begin large scale field evaluations. Evaluate persistence and develop protocols for suppression of SPW populations.			
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Yr. 4: Limited field trials to determine effectiveness and survival of resistant natural enemy strains.			
D.8 Systematics of predators, parasites and pathogens.	Yr. 4: Describe new taxa, prepare keys, characterize phylogenetic relationships.			

SECTION E: CROP MANAGEMENT SYSTEMS AND HOST PLANT RESISTANCE

Co-Chairs: Eric Natwick and Alvin Simmons

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): Allen Carson Cohen, C.C. Chu, T.J. Henneberry, Kelli Nafziger, and Richard Percy.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory, 4135 E. Broadway Road, Phoenix, AZ 85040.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1995.

Characteristics of Cotton Leaves Related to Whitefly Feeding

We examined seven types of cotton (DP 5415, E-15, DP 8709, S6, B333, H_2H_2 and St 474) to determine leaf characteristics that might confer resistance to whiteflies and other homopterous pests. The E15 had the thinnest leaves (about 230 µm); while the St 474 had the thickest leaves (about 360 µm). The E15 had the most superficial minor veins, about 100 µm from the abaxial surface. The St 474 had the deepest minor veins, about 140 µm. We found that the depth of vascular bundles was >95% correlated with leaf thickness. The E15 and S6 varieties had the greatest length of vascular bundles (2200 and 2100 µm per 250,000 μm^2), and the DP 8700 and St 474 had the shortest length of vascular bundles per unit surface area. The variety of leaf characteristics in addition to leaf hairiness offer several promising genetic attributes that relate to resistance of cotton to homopterous pests.

Investigator's Name(s): Hollis M. Flint, Steven E. Naranjo, Joseph E. Leggett, and Thomas J. Henneberry.

Affiliation & Location: USDA-ARS, Western Cotton Research Laboratory Phoenix, AZ.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: April 1993 to October 1995.

Effects of plant water stress on pest and beneficial insects infesting short and long staple cotton with emphasis on management of *Bemisia tabaci*

The effects of plant water stress on insects infesting short-staple cotton, *Gossypium hirsutum* L., and long staple cotton, *Gossypium barbadense* L., were studied in 1993 and 1994 in large replicated field plots in central Arizona. In 1993, we compared the effects of weekly or biweekly irrigation (7- or 14-day intervals) and two irrigation termination dates (27 August, 10 September) on insects in Deltapine 50 (DPL-50), and Pima S-7. In 1994, we compared weekly or biweekly irrigation and conventional (mix of fenpropathrin and acephate at 0.17 and 0.56 kg/ha, respectively) or biorational (buprofezin at 0.28 kg/ha) insecticide treatments applied at thresholds of 1, 5, or 10 adult sweetpotato whiteflies, *Bemisia tabaci* (Gennadius), per fifth main-stem node leaf. Seasonal populations of eggs, nymphs, or adults of *B. tabaci* were reduced 45-69% and 22-36% in weekly irrigated compared with biweekly irrigated plots in 1993 and 1994, respectively. In 1993, DPL-50 had more whiteflies of all stages than Pima S-7 but crop termination dates had no effect on seasonal densities of whiteflies. In 1994, conventional insecticide applications provided greater control of whiteflies than the biorational insecticide, while application thresholds of 1 adult whitefly per leaf resulted in lower whitefly populations than thresholds of 5 or 10 adults per leaf. Weekly irrigated plots required 1-2 fewer applications of insecticide depending on the threshold used. Leaf water potentials (-bars) measured at 3, 7, or 14 days post irrigation in 1993, indicated greater plant water stress in biweekly irrigated cotton at 7 and 14 days post irrigation, than in weekly irrigated cotton at 7 days post irrigation. There were no differences at 3 days post irrigation. Yields of seedcotton were significantly greater from weekly irrigated plots in 1993 and biweekly irrigated plots in 1994. In 1994, yields were greater in plots treated with conventional compared with biorational insecticide. Yields were also greater at thresholds of 1 than at 5 or 10 adult whiteflies per leaf, however, the incidental control of *L. hesperus* at early sprays of 1 adult per leaf complicates the interpretation of threshold level on yield results. Treatment comparisons of stickiness or for soluble sugars in lint were non-significant for both years and in no case were the results of economic importance. Fiber quality tests indicated finer micronaire values from weekly irrigated cotton both years and variable results for fiber length, strength, and elongation. Combining reduced plant water stress of weekly irrigation with conventional insecticides provided the best control of *B. tabaci*.

Investigator's Name(s): Luko Hilje.

Affiliation & Location: Plant Protection Area, CATIE, Turrialba, Costa Rica.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January 1993 - December 1995.

Reduction of Whitefly Adult Numbers and Delay of Geminivirus Dissemination in Tomatoes, by Living Soil Covers, in Costa Rica

In Costa Rica, fresh-market tomatoes are grown mainly by small farmers. The crop is affected by *Bemisia tabaci* biotype C (*sensu* Dr. Judy Brown), which does not breed on it. However, tomato plants are severely injured by geminiviruses associated with the Tomato Yellow Mosaic disease, if the plants become infected during their critical period of susceptibility (first 60 days after sowing).

To deal with the problem, a two-phase preventative management scheme has been proposed. The first phase (during the first 30 days after sowing), is protection of seedbeds with fine nets, which renders high-quality, virus-free seedlings. For the second phase (the first 30 days after transplanting), a variety of cultural practices is being investigated, including living soil covers. These supposedly mask the crop, and thus interfere with its location by the vector.

In a first experiment, a mixture of spontaneous weeds, as well as the legume *Arachis pintoi* (perennial peanuts) significantly reduced whitefly adult numbers and delayed virus dissemination, when compared to a control (bare soil) and three inert covers (yellow and light green plastics, and rice husk). Similar results were obtained in a second experiment, which involved a mixture of spontaneous weeds, the legume *Styzolobium deeringianum* ("mucuna"), and "cinquillo" (*Drymaria cordata*: Caryophyllaceae); they were similar to silver plastic, and were all superior to a control. In a larger on-farm trial, the "cinquillo" was individually compared to a control, with similar results.

Future research will explore other native wild plants that compete least with the crop, cover quickly, establish easily, and do not have serious pest or disease problems. In addition, they must be evaluated in their potential roles as whitefly hosts and geminivirus reservoirs.

Investigator's Name(s): D. Michael Jackson and M.W. Farnham.

Affiliation & Location: USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1993 - 1995.

Field Evaluation of Collard Genotypes for Resistance to Whiteflies

Fourteen collard genotypes, *Brassica oleraceae* L. Acephala group, were evaluated for resistance to naturally occurring whiteflies (primarily *Benisia argentifolii* Bellows & Perring) in replicated field plots at Charleston, SC from 1993-1995. Plants were started from seed in the greenhouse and transplanted to the field on March 30, 1993, April 11, 1994, & April 19, 1995. Plots were a single row of 25 plants, and there were four replications each year. Whitefly adults were counted on five plants per plot on June 8, 1993, May 13, 1994, June 20, 1994, and July 5-10, 1995. Nymphs and eggs were counted on 4 (1993), 5 (1994), or 6 (1995) detached leaves per plot on June 23, 1993, June 24, 1994, and July 12-17, 1995. A single leaf per plant was examined in 1993 and 1994, whereas two leaves (leaf positions 4 and 10 from the top of the plant) were examined in 1995. An additional field test was conducted late in the 1995 season. Six replications of four collard genotypes (Morris Heading, Blue Max, Green Glaze-Glossy, and Green Glaze-Nonglossy) were transplanted on September 12, 1995 Adult whiteflies were counted on 10 plants per plot on November 28, and eggs and nymphs were counted on 10 leaves per plot (5 leaves from leaf position 4 and 5 leaves from leaf position 10) on December 1-5, 1995.

Three glossy collard genotypes (SC Glaze, P.Smith, and Green Glaze-Glossy) were very resistant to whitefly infestations in all field experiments. These genotypes have reduced leaf waxes, which causes their glossy or shiny appearance. Whitefly adults per plant averaged only 19.6, 26.8, and 35.0 for Green Glaze-Glossy, SC Glaze, and P.Smith, respectively, compared to over 400 whitefly adults per plant on the commercial cultivar Morris Heading. The three glossy collard genotypes also had significantly fewer eggs and nymphs than any of the other 11 genotypes. The three glossy lines averaged only 0.1 nymphs/cm^2, compared to over 2.5 nymphs/cm^2 for the susceptible genotypes. Green Glaze segregated for a glossy and a nonglossy type. Green Glaze-Glossy was one of the most resistant collards, whereas Green Glaze-Nonglossy was one of the most susceptible to whitefly infestations.

Two F_1 hybrids (Blue Max and Top Bunch) had consistently and significantly fewer whitefly adults, nymphs, and eggs than the open-pollinated collard cultivars (Morris Heading, Georgia, Vates, and Champion), but they were not as resistant as the glossy collards. Top Bunch and Blue Max are of special interest because, unlike the glossy collards, they are normal in appearance. However, the mechanism of resistance to whiteflies is unknown in these genotypes.

Overall rankings for resistance to whiteflies were consistent from year to year among collard genotypes. Each season, there was a significant correlation between counts of whitefly adults and counts of eggs + nymphs. For 1995, there were approximately equal numbers of whitefly eggs on leaf positions 4 and 10. Most nymphs were counted on leaf position 10; and there were few nymphs on leaf position 4, probably because the eggs on these leaves had not yet hatched. Results from the late 1995 field experiment were consistent with results from the 3-years of spring plantings.

Investigator's Name(s): Heather J. McAuslane[1], Rhoda Golub[1] and David J. Schuster[2].

Affiliation & Location: [1]Entomology & Nematology Departments, University of Florida, Gainesville, Florida, and [2]Gulf Coast Research and Education Center, University of Florida, Bradenton, Florida.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January - June 1995.

Assessing Resistance to Silverleaf Whitefly of Tomato Mutants for Foliar Pubescence

The following greenhouse and field experiments were performed to determine the influence of foliar pubescence of cultivated tomato, *Lycopersicon esculentum*, on resistance or susceptibility to silverleaf whitefly, *Bemisia argentifolii* (*B. tabaci*, strain B). Seeds of 7 cultivars and 12 isogenic or near-isogenic mutants varying for foliar pubescence were obtained from C.M. Rick Tomato Genetics Resource Center (Department of Vegetable Crops, University of California, Davis). The following accessions were acquired: 1) 'Ailsa Craig' (LA2838A), LA3172 (hairless near-isoline), and LA3186 (wooly near-isoline); 2) 'Rutgers' (LA1090), LA1531 and LA258 (wooly isolines); 3) 'San Marzano' (LA180) and 2-69 (hairs suppressed isoline); 4) 'Condine Red' (LA533) and LA937 (hairless isoline); 5) 'Canary Export' (LA3228) and LA2015 (hairs "singed" isoline); 6) 'VF145' (LA1222) and LA1908 (wooly isoline); 7) 'VF36' (LA490), 3-71 (hairy isoline), 3-95 and 3-126 (hairless isolines).

Oviposition choice tests were performed in the greenhouse. One plant of each genotype was placed in a 60x60x60-cm chiffon cage and 45 mated female whiteflies were added. One experiment consisted of choices among 'Ailsa Craig', LA3172, and LA3186, while a second experiment consisted of choices among 'Rutgers', LA1531, and LA258. Whiteflies resting on each plant were counted daily for 3 days. After that time, leaves were removed from the plants, their areas measured, and eggs were counted. Significantly fewer adults and eggs were counted on the wooly near-isoline, LA 3186, than on 'Ailsa Craig' or LA 3172, the hairless near-isoline. No significant differences were found among 'Rutgers' and its two wooly isolines.

A field experiment was initiated in Bradenton on March 20 when transplants were planted on raised beds covered with black polyethylene mulch. The field plot consisted of 2 150-ft-long rows separated by 5 ft and was irrigated by a seepage subirrigation system. Single plants were replicated 10 times in a completely randomized design. 'Sunny' was the control susceptible cultivar. On May 24, June 7, and June 20, 2 terminal leaflets from 6th leaves (counting from the top) and 2 terminal leaflets from 8th leaves were collected from each plant. The area of each leaflet was measured and the numbers of eggs, nymphs and red-eyed nymphs (pupae) were recorded on a per 10 cm^2 basis. On April 13 and on May 10, numbers of glandular (type VI) and nonglandular (types II, III and V) trichomes were counted per 8 mm2 on terminals from the 6th leaves.

Whitefly populations were low until June 7. Eggs were most abundant on June 7, whereas populations of nymphs and red-eyed nymphs were greatest on June 20. Numbers of immature whiteflies did not differ significantly within the 'Ailsa Craig', 'San Marzano', 'Condine Red', 'Canary Export' or 'VF145' accession groups, nor did they differ from the control cultivar 'Sunny', despite differences in density of foliar pubescence. Within the 'Rutgers' accession group, LA1531, a wooly isogenic line derived from 'Rutgers', supported significantly more immature whiteflies than either 'Rutgers' or another wooly isoline or 'Sunny'. Similarly, in the 'VF36' accession group, 3-71 supported more whiteflies than either 'VF36', or two other isogenic lines or 'Sunny'.

In conclusion, no sources of resistance to silverleaf whitefly were discovered and the influence of foliar pubescence on whitefly populations in this experiment was variable.

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Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January - November 1995.

Leaf Pubescence as a Factor in Antixenosis Resistance of Soybean to Silverleaf Whitefly

A glabrous soybean isoline (D90-9216) supported significantly fewer whiteflies than pubescent (D75-10169) or hirsute isolines (D90-9220) in previous field experiments. We wished to determine the mechanism of the partial resistance observed.

Oviposition Choice Test. We placed one plant of each of the 3 soybean isolines in a 60 x 60 x 60-cm chiffon cage in the greenhouse and added 150 mating pairs of whiteflies. For 3 d, we counted the number of whiteflies resting on each leaf of each plant. At the end of 3 d, leaf areas were measured, and eggs were counted. 24 replicates were performed. Whiteflies rested on the 3 soybean isolines in equal proportion to the available leaf area. Their distribution among the isolines did not change over the 3-d experiment but, during that time, whiteflies moved from the lower leaves to the upper leaves. A significantly smaller proportion of the eggs was laid on the glabrous isoline (0.27 weighted relative proportion) than on pubescent (0.36) or hirsute isolines (0.38).

Vertical Distribution of Oviposition within Soybean Isolines. Plants of each of the 3 isolines were placed individually in cylindrical cages in the greenhouse. 75 mating pairs of whiteflies were added to each cage. After 3 d, leaf areas were measured and eggs were counted on each leaf (unifoliate node to 6th trifoliate node). Trichome density was determined. 25 replicates were performed. Distribution of eggs within a plant differed by genotype. Eggs were most common on the 2 oldest and 2 youngest leaves of glabrous soybean. On hirsute and pubescent soybean, eggs were most common on the 3 oldest leaves and least abundant on the youngest leaves which were the hairiest.

Clip-Cage Oviposition Choice Tests. Clip cages, consisting of a 9-cm-diameter plastic petri-dish with 2 2-cm-diameter holes in the lid, were placed below the undersides of 2 leaves between which whiteflies were allowed to choose, with access to 1 leaf type through each hole. Three choice situations were set up: 1) glabrous and pubescent leaflets, 2) pubescent and shaved (with an electric razor) pubescent leaflets, or 3) glabrous and shaved pubescent leaflets. 7-10 pairs of mating whiteflies were added. Eggs were counted on the leaflets after 3 d. This experimental design was repeated using glabrous and hirsute isolines. A second experiment compared oviposition on paired leaflets within a plant (pubescent versus shaved pubescent, and hirsute versus shaved hirsute). Glabrous leaflets were less preferred for oviposition than hirsute but not pubescent leaflets. Shaved hirsute leaflets were less preferred than unshaved hirsute leaflets.

Survival and Development on Isolines. 2 vial clip-cages were attached to 10 plants of each of the 3 isolines. 15 female whiteflies were added to each clip cage. After 48 h, whiteflies and cages were removed and eggs were counted. Emerged adults were removed daily and sexed, and exuviae were counted and removed also. Whiteflies laid significantly fewer eggs on glabrous soybean (72 ±5, mean ±SEM) than on hirsute (102 ±8) or pubescent (99 ±7) soybean. Survival to adulthood ranged from 72% (hirsute) to 80% (pubescent) and did not differ among the isolines. Sex ratio ranged from 40% female (glabrous) to 44% female (hirsute) and did not differ among the isolines. Developmental rate was also similar for the 3 isolines.

Investigator's Name(s): Heather J. McAuslane[1], Susan E. Webb[2] and Gary W. Elmstrom[2].

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Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: May - October 1995.

Resistance in Germplasm of *Curcurbita pepo* to Squash Silverleaf

Elite breeding lines and susceptible commercial varieties of *Cucurbita pepo* L. (zucchini and yellow crookneck squash) and accessions of two wild species, *Cucurbita ecuadorensis* Cutler and Whitaker and *Cucurbita martinezii* Bailey, were evaluated in spring and fall of 1995 for resistance to silverleaf whitefly, *Bemisia argentifolii* (= *B. tabaci* strain 'B'), and to squash silverleaf, a physiological disorder associated with feeding by *B. argentifolii*. Two zucchini breeding lines (Sunseeds 3 and A21-7) and two yellow squash breeding lines (A24-10 and K26-4) were selected based on their low levels of silverleaf in previous field screenings.

Populations of whitefly and silvering severity were greater in the spring field season than in the fall. In general, the yellow squash variety, 'Supersett', and the two breeding lines (A24-10 and K26-4) supported larger populations of whitefly than the zucchini variety, 'Elite', and A21-7 and Sunseeds 3, the zucchini breeding lines. However, whitefly populations within the yellow squash varieties or within the zucchini varieties did not differ significantly. In contrast, 'Elite' was severely silvered in the spring (average rating of 4.8 at the end of the season) while Sunseeds 3 never exhibited silverleaf and only one plant of A21-7 exhibited slight silvering (rating of 1). 'Supersett' was usually significantly more silvered than the yellow squash breeding lines, but the lines nevertheless exhibited significant levels of silvering (average rating of 3.2 compared to 3.9 for 'Supersett' at the end of the spring season). Four accessions of the two wild species, *C. ecuadorensis* (PIs 540895 and 432443) and *C. martinezii* (PIs 512099 and 438698), all supported moderate populations of whiteflies and developed silverleaf.

In the case of the zucchini breeding lines, silverleaf severity was not related to density of immature whiteflies. Silverleaf severity was linearly related to density of immature whiteflies for 'Elite', 'Supersett', and for the two yellow squash breeding lines. Resistance to silverleaf in the zucchini breeding lines may be due to some form of tolerance to the effects of whitefly feeding, and is being investigated further.

Investigator's Name(s): John W. Norman Jr.

Affiliation & Location: Texas Agricultural Extension Service, Weslaco, Texas.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: 1990 - 1995.

Silverleaf Host Plant Resistance in the U.S.: A Status Report

Whitefly host-plant resistance research is an ongoing effort in the U.S. Several characters which make plant cultivars less susceptible or attractive to whiteflies have been observed in currently marketed plant materials. Leaf trichomes-whitefly relationships have been the area to receive most of the attention to date. Leaf-trichome-whitefly relationships in squash, melons and cotton have all been evaluated. However, to date, no reports of plant materials resistant to Silverleaf whiteflies being delivered to the grower market have been received.

Investigator's Name(s): R.G. Percy[1], P. Ellsworth[2], and H.S. Moser[2].

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Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: April 1995 - September 1995.

Field Preference of Silverleaf Whitefly among Pima Cotton Genotypes

In 1995 we initiated an evaluation of silverleaf whitefly preference among 22 Pima cotton genotypes varying in pubescence, leaf shape, leaf size, foliar color, and maturity time. The 22 lines were planted in the field at Maricopa, AZ on April 13, 1995. Test plots consisted of single row plots, 9.1 m long, separated by two rows of the commercial cultivar, Pima S-7. Plots were planted in a three replicate, randomized block design. Sampling within plots began on June 8 and continued at 7-10 day intervals until August 10. Adult whiteflies were counted on the fifth mainstem leaf below the apical meristem on 10 plants in each plot. Leaf discs were removed from 5 leaves per plot for determination of egg, nymph, and leaf trichome numbers. Egg, nymph, and trichome numbers were determined for a 6.45 cm^2 area and expressed on a cm^2 basis. Trichomes were counted as individuals, regardless of whether they were uniseriate, biseriate, or stellar.

The commercial check cultivar PS-6 (3.6 trichomes/cm^2) was observed to have 27.0 adults/leaf, 37.4 eggs/cm^2, and 6.9 nymphs/cm^2 on August 10. On the above date, significant positive relationships between trichome, egg, and nymph densities were observed within the 0.02 to 5.6 trichomes/cm^2 density range. A smooth (1.1 trichomes/cm^2), okra-leaf genotype was observed to have 5.6 adults/leaf, 1.8 eggs/cm^2 and 0.9 nymphs/cm^2. In comparison, a large leafed, hairy (4.1 trichomes/cm^2) genotype was observed to have 67.4 adults/leaf, 77.5 eggs/cm^2, and 12.4 nymphs/cm^2. There appeared to be an extreme non-preference of the whitefly for the smooth (0.02 trichomes/cm^2), small leafed, diploid species *Gossypium thurberi*. The above wild cotton species had 1.8 adults/leaf, 0.1 eggs/cm^2, and 0.0 nymphs/cm^2 on August 10. Preference was apparent for a cluster-fruiting genotype and a yellow-green foliage genotype. The cluster-fruiting genotype (cl_2cl_2 Pima cluster) had 55.5 adults/leaf, 103.9 eggs/cm^2, and 20.4 nymphs/cm^2 on August 10. The yellow-green foliage genotype (v_7v_7) had 97.4 adults/leaf, 74.4 eggs/cm^2, and 8.3 nymphs/cm^2 on the above date.

Analyses of the various plant traits and collection dates continue. A subset of the genotypes in the investigation are being evaluated in no-choice cage experiments. A repeat of the present investigation is planned for the 1996 growing season.

Investigator's Name(s): David G. Riley, Weijia Tan, Dan Wolfenbarger.

Affiliation & Location: Texas Agricultural Experiment Station, 2415 E. Hwy 83, Weslaco, Texas 78596.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: January 1995 - December 1995.

Bifenthrin resistance in the silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring [previously b-strain sweetpotato whitefly, *Bemisia tabaci* (Gennadius)], was inherited as an incompletely dominant factor. Back-crosses of bifenthrin resistant (R) and susceptible (S) parental colonies to their respective hybrids demonstrated significant segregation. Two backcrosses with F_1 males did not segregate; thus, these were consistent with the condition of facultative arrhenotoky (diploid females and haploid males) suspected for *Bemisia*. However, segregation occurred with the other two F_1 male backcrosses. Also, probit lines for males from mated and unmated resistant females were significantly different, complicating the arrhenotokous mode of inheritance.

Probit lines for the reciprocal F_1 crosses (RR female x S male, SS female x R male) were significantly different. Resistance appeared to be inherited to a greater degree from females as males. The estimates of degree of dominance (-1, recessive; +1, dominant) for RR female x S male and SS female x R male were 0.91 and 0.51, respectively. The resistant LC_{50} to susceptibile LC_{50} ratios in the backcross populations for SS/SR and RR/RS were closest to 0.6:1 and 1: 0.9, respectively. Plateaus occurred in both F_1 backcrosses at 35—45% mortality. We suggest that multiple genes and ploidy incidences complicated observed resistance to susceptibility ratios in the progeny. Additive inheritance of multiple genes and/or parental extranuclear effects could have been involved.

High, stable bifenthrin resistance (608-fold) was observed for six months in an isolated, resistant colony derived from a bifenthrin-selected greenhouse colony. This could potentially threaten insecticide resistance management for the silverleaf whitefly, especially in enclosed greenhouses. The measured high level of stability of resistance could pose a threat to resistance management in the silverleaf whitefly under isolated conditions, such as in an enclosed greenhouse. However, under field conditions resistance to bifenthrin has been reported to be variable. Therefore, a better understanding of the bionomics of resistant whitefly populations is needed to understand the fate of resistance under field conditions.

One of the backcrosses produced a whitefly population that had double the net reproductive rate of the original parent population and carried the resistant trait. Thus under lab conditions a highly reproductive "super bug" with insecticide resistance could be crossed and selected for. This is the first experimental documentation that selection for resistant populations of whiteflies can directly affect reproduction.

Investigator's Name(s): D.J. Schuster, P.A. Stansly, D.E. Dean, and J.E. Polston.

Affiliation & Location: University of Florida, Gulf Coast Research & Education Center, Bradenton, Florida.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: September 1993 - June 1995.

Potential of Companion Plantings for Managing Silverleaf Whitefly and Tomato Mottle Geminivirus on Tomato

Squash and other cucurbit crops were investigated as potential trap crops for the silverleaf whitefly (SLWF) on tomato. In previous replicated field trials at GCREC, more SLWF adults were observed on squash than on tomato, eggplant or okra. In the fall of 1993, yellow summer squash was planted on one half the length of either three or six rows on one side of four fields on conventional tomato farms. The other half of the length of the outer rows of each field was transplanted with tomatoes. The remaining rows of each field were also transplanted to tomatoes. The tomatoes adjacent to the outer rows of squash and tomatoes were sampled weekly for adult SLWF using the beat pan method and observed weekly for incidence of TMoV symptoms. In the fall of 1994, yellow summer squash was planted on one half the length of six rows on one side of three fields on conventional tomato farms. The other half of the length of the outer six rows of each field was transplanted with tomatoes. All squash and tomato plants were treated at transplanting with 16 ozs/acre of imidacloprid (Admire 2F). The tomatoes adjacent to squash and the tomatoes adjacent to tomatoes were sampled as above for adult SPWF and for incidence of TMoV symptoms.

The results from the fall 1993 evaluation of squash as a trap crop indicated that six row plantings of squash resulted in a delay in virus incidence on adjacent tomato but had no significant effect on the number of SLWF adults. The three row plantings of squash had no effect on either the number of SLWF adults or virus incidence. In the fall of 1994, all plants were treated with imidacloprid and the numbers of SLWF adults and percent TMoV were very low. Nevertheless, the number of SLWF adults observed on tomatoes planted adjacent to squash were greater than those observed on tomatoes planted adjacent to tomatoes during the first five weeks following transplanting.

A replicated trial at the Southwest Florida Research & Education Center (SWFREC) in the spring of 1994 occupied 2.4 acres. There were 16 pairs of single row beds (blocks), 12 divided into 4 double-row plots and 4 divided into 5 double-row plots. Inside rows of all plots were planted to tomato. Outside rows on one plot in the 4 plot blocks was planted to zucchini and another plot to an alternating mixture of cucumber, watermelon and wintermelon, with the remaining two plots all tomato. All rows in the 5 plot blocks were planted to tomato except for one plot with a ditch row planted to zucchini. The following treatments were assigned randomly to the remaining four plots: 1) conventional insecticide (weekly fenpropathrin plus methamidophos alternated with endosulfan), 2) biorational insecticide (weekly rotation of mineral oil, buprofezin, or *Nicotiana gossei* extract), 3) imidacloprid at transplanting, or 4) untreated. In the spring of 1995, tomato was planted next to tomato or eggplant either treated with imidacloprid at transplanting or not treated. SLWF adults were sampled weekly using the beat pan method and nymphs per plot per cm2 were estimated weekly on three tomato trifoliates, three squash leaves and one leaf from each of the three cucurbit crops and eggplant. Plots were surveyed weekly for TMoV symptomatic plants.

In 1994, there were fewest SLWF adults and nymphs and least TMoV on tomato treated with imidacloprid. There were no significant differences in the number of adults between tomatoes planted alone, those planted in association with cucurbit crops or those sprayed weekly with insecticides. On one sampling date, fewer SLWF nymphs were observed on tomatoes grown associated with squash relative to tomatoes grown alone or tomatoes associated with other cucurbits. On another date, the percentage of new TMoV symptomatic tomato plants grown in association with cucurbits was less than tomato alone but similar to tomato sprayed with conventional insecticides. In general in 1995, fewer SLWF adults and nymphs were observed on tomato adjacent to imidacloprid-treated eggplant than on tomato adjacent to nontreated crops.

Investigator's Name(s): D.J. Schuster, A.A. Csizinszky, D.E. Dean, and J.E. Polston.

Affiliation & Location: University of Florida, Gulf Coast Research & Education Center, Bradenton, Florida.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: September 1994 - June 1995.

UV-Reflective Plastic Soil Mulches for Management of the Silverleaf Whitefly and Tomato Mottle Geminivirus on Tomato

Two UV-reflective aluminum mulches that are commercially available and two that are under commercial development were evaluated on 3-13 plant rows with 5 ft row spacing and 1.5 ft plant spacing. Plots were replicated 4 times in a randomized complete blocks design. Mulch treatments consisted of metallic aluminum film (designated aluminum) on two brands of white plastic and painted aluminum (designated silver) on black or white plastic. All four plastic mulches were compared to a white plastic control and were evaluated with a white strip down the middle to try and alleviate alleged effects of heat reflected onto the plants by the aluminum surfaces. All plants in each plot were inspected weekly for symptoms of tomato mottle geminivirus (TMoV) beginning one week after transplanting. The numbers of immature lifestages of the silverleaf whitefly (SLWF) were counted biweekly on 10 leaflet samples/plot. The number of SLWF adults were estimated weekly by counting the number on 10 leaflets per plot. Ten contiguous plants in each plot, regardless of TMoV infection, were harvested four times for estimating yield of marketable fruit. All data except TMoV incidence were collected from the middle row of each plot.

Fewer SLWF adults generally were observed on plants growing on the aluminum on white plastics with or without a white strip and on the silver on black plastic without a strip compared to plants growing on white plastic. The numbers of SLWF nymphs and pupae did not differ significantly from the control on any week of sampling. In general, the TMoV rates were significantly less for tomatoes grown on the aluminum mulches with or without a white strip and the silver on black plastic without a white strip than the rate for tomatoes grown on white plastic. Tomato plants grown on silver mulches with a white strip down the middle of the bed surface did not differ from plants grown on white plastic with respect to the numbers of SLWF adults or immatures or the cumulative % TMoV. Also, plants grown on the silver on white mulch tended to have the same or more whiteflies and a similar incidence of TMoV relative to plants grown on the white plastic. Plant height was not reduced by any UV-reflective mulch as suggested by growers. On the contrary, tomatoes growing on the aluminum mulches with white strips were taller than tomatoes growing on white plastic on weeks 7 and 9 after transplanting. This is probably a reflection of the delay in TMoV incidence rather than direct effects on plant growth. No UV-reflective mulch resulted in greater yields than the white mulch; however, plants growing on the silver on white plastic without a white strip generally yielded less fruit than plants growing on the other two comparable UV-reflective mulches.

One half the length of six rows on one side of three fields on commercial tomato farms were covered with white plastic and the other half of the length was covered with a commercial silver on black plastic. Tomatoes were treated at transplanting with 16 ozs/acre of imidacloprid (Admire 2F). The tomatoes in each of the mulch treatments were sampled weekly for adult SLWF using a beat pan sample and observed weekly for incidence of TMoV symptoms. Ten tomato plants on each mulch at each farm (40 plants/farm) were harvested at least twice to coincide with commercial harvest and fruit were evaluated for marketability.

Fewer SLWF adults and fewer TMoV-infected plants were observed during the first five weeks following transplanting on tomatoes grown on UV-reflective aluminum plastic mulch than on tomatoes grown on white plastic mulch. Despite the imidacloprid treatment, the number of SLWF adults on plants on aluminum mulch was about a third that on plants on white mulch; however, differences disappeared after about five weeks when plant growth and pesticide residues obscured the plastic film. The weight and number of fruit yielded were not different between the mulches.

Investigator's Name(s): Alvin M. Simmons and D. Michael Jackson.

Affiliation & Location: USDA-ARS, U.S. Vegetable Laboratory, Charleston, SC.

Research & Implementation Area: Section E: Crop Management Systems and Host Plant Resistance.

Dates Covered by the Report: August - November 1995.

Abundance of Parasitoids of *Bemisia argentifolii* in Imidacloprid Treated Vegetables

The abundance of native parasitoids of *Bemisia argentifolii* was studied in four vegetable crops with and without imidacloprid. Three fields were set up, each with cantaloupe, collard and tomato. An additional field was setup with sweetpotato. Each crop received either no treatment or a foliar treatment of imidacloprid (Provado @ 0.5 lb/acre for the season). The only other pesticides used were pre-plant herbicides. Five imidacloprid treatments were made at two-week intervals starting 5 September and ending 31 October. Starting one day post treatment, yellow sticky cards were placed in each plot. After one week, the sticky cards were taken to the laboratory for examination for *B. argentifolii* and its parasitoids. Sticky cards were used following each insecticide treatment.

Overall, 61% of the captured parasitoids were from the non-treated plots and 39% were from the imidacloprid-treated plots. The primary parasitoid was *Encarsia nigricephala* (55%) followed by *Encarsia pergandiella* and *Eretmocerus sp.*, each at ca. 20%. Relative species distribution was not affected by imidacloprid. In cantaloupe and sweetpotato, the number of parasitoids captured was positively correlated with the number of whiteflies captured. Whitefly and parasitoid populations peaked in all crops during the third week of sampling (first week of October). On a per trap basis, parasitoid capture was highest in cantaloupe (ca. 15 per trap) and lowest in tomato (ca. 5 per trap). Following relatively high populations of whiteflies during the summer, whitefly abundance was depressed during the fall. Frequent rains during the first half of the study and low temperatures during the second half of the study may have adversely affected the populations of the whitefly and parasitoids. Moreover, the wet conditions precluded the chance to manually control weeds during the first half of the study. Except sweetpotato, all other plots were weedy through the end of the study.

TABLE E. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
E.1 Determine effect of traditional crop production inputs on SPW population development.	Yr. 4: Determine possibility of exploiting or manipulating crop production methods as a factor in SPW management.			
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Yr. 4: Determine potential of manipulating cultivated host sequences during growing season to reduce SPW populations.			
E.3 Determine effect of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SPW control methods.	Yr. 4: Identify cultural factors with greatest potential for adversely affecting SPW population development and improve yield.			
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Yr. 4: Begin to characterize resistance mechanisms and to identify chemical/ morphological components.			
E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Yr. 4: Determine interaction of selected plant types and SPW populations in the field.			
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Yr. 4: Continue the transfer program.			

SECTION F: INTEGRATED TECHNIQUES, APPROACHES, AND PHILOSOPHIES

Co-Chairs: Dennis Kopp and John Norman

- **Abstracts**
- **Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan**

Investigator's Name(s): J.C. Allen[1], D.J. Schuster[1], P.A. Stansly[1], D. Byrne[2], J.F. Pari
T.M. Perring[4], D.G. Riley[5], C.G. Summers[6].

Affiliation & Location: University of Florida[1], University of Arizona[2], California State University Fresno[3], University of California, Riverside[4], Texas A&M University[5], University of California, Davis[6].

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1995.

Large Scale Cropping Patterns in Relation to Reproduction and Movement of Silverleaf Whitefly

1. Modeling the Spatiotemporal Dynamics of SLW in Large Cropping Systems.

OBJECTIVE: Improve the efficiency of a model developed on SLW movement and reproduction in crop-grid spatial resource systems with large numbers of crops.

A model developed for studying insect dynamics in crop-grid spatial resource systems was revised to allow for more efficient simulation of SLW in spatial systems with large numbers of crops. We ran the modified model using a resource map on the San Joaquin Valley, California, that contained seventy-six crops. The final dynamics with the modified model were no different from those observed before modification; however, simulation efficiency was vastly improved. Major modifications were made in the way we handled dispersal.

2. Study a SLW System and Test the Spatiotemporal Model.

OBJECTIVE: Study SLW dynamics in a small heterogeneous crop system and test the spatiotemporal model on this system.

Whitefly dynamics were studied at a mixed-crop organic farm located on Pine Island, Florida. Population data were collected from five spatially and temporally varying crops (tomato, eggplant, cucumber, zucchini, and pepper) by beat-pan sampling and visual scouting. Parasitism was determined in rearing studies. Sampling data indicated that SLW infestation levels varied with tomato > eggplant > cucumber = zucchini > pepper. Interaction of planting date, crop and temperature seems to be a major determining factor in whitefly dynamics. Percentage parasitism reached as high as 80%. We tested our model on the system. Model simulation results compared reasonably with trends observed in the sampling data, and were highly sensitive to natural enemy parameters. Simulated parasitism fluctuated but showed the same general trends as observed parasitism.

3. Studies of Existing Agricultural Crop Systems Where SLW is a Problem.

OBJECTIVE: Classify and map crops in existing agricultural systems from Landsat data.

Four Landsat subscenes on the Imperial Valley, CA for the 1994-1995 cropping season were acquired for the following dates: 1 September 1994, 21 December 1994, 23 February 1995, and 30 May 1995. Globally positioned ground-truth data were collected as close as possible to the subscene dates, i.e., 1 September 1994, 10 December 1994, 1 February 1995, and 13 May 1995. Efforts to classify these images using the isodata method in the MIPS software package have not been as successful as in the San Joaquin Valley classification previously done. We have tried other classification methods but the creation of a training set from the ground-truth data followed by maximum likelihood classification gave the best results so far. The major problem encountered thus far is the similarity between signatures for alfalfa, sudan, bermuda, cotton, and asparagus.

We would like to acknowledge the USDA NAPIAP Program for its support of these studies.

Investigator's Name(s): S.L. Birdsall, D. Ritter and P.L. Cason.

Affiliation & Location: Imperial Valley Agricultural Commissioner and Whitefly Program Coordinator, respectively, El Centro, CA.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1991 - 1995.

Economic Impact of the Silverleaf Whitefly in Imperial Valley, California, from 1991 to 1995

Bemisia argentifolii Bellows and Perring has been an economic pest of epidemic proportions in the Imperial Valley, CA since 1990. Dollar losses in crop value as a result of reduced production and damage have been extensive. The impact of these losses have also been reflected in other facets of the agricultural community such as farm labor, employment, private sector sales and personal income of industries supporting the farm community. We have tabulated losses for apiary products, vegetable and melon crops, field crops and cotton for the 1994-1995 growing season to update our 1994 report (Birdsall et al. 1995)[5].

	Losses In			Reduction In	
Year	Crop Value	Private Sector Sales	Personal Income	Direct Employment No.	Direct and Indirect Employment No.
1991-1992[1]	121,163,092	196,852,408	27,936,441	3,139	5,395
1992-1993[2]	100,497,225	172,152,282	24,560,743	2,787	4,773
1993-1994[3]	106,589,663	182,395,938	29,157,250	3,258	5,196
1994-1995[4]	91,526,503	153,810,836	23,613,430	2,658	4,293
TOTALS	419,776,483	705,211,464	105,267,864	11,842	19,657

[1] May 1991 to April 1992
[2] May 1992 to Jan 1993
[3] May 1993 to April 1994
[4] May 1994 to April 1995
[5] Birdsall, S.L., D. Ritter, and P.L. Cason. 1995. Economic impact of the silverleaf whitefly in Imperial Valley, California, p. 162. *In* Silverleaf Whitefly 1995 Supplement to the 5-Year National Research and Action Plan, T.J. Henneberry, N.C. Toscano, R.M. Faust, and J.R. Coppedge (eds.), USDA-ARS, ARS 1995-2, National Technical Information Service, Springfield, VA.

Investigator's Name(s): C.C. Chu, E.T. Natwick, H.H. Perkins, T.J. Henneberry, and A.C. Cohen.

Affiliation & Location: USDA-ARS, Western Cotton Laboratory, Phoenix, AZ, University of California, Cooperative Extension, Holtville, CA, and USDA-ARS, Cotton Quality Research Station, Clemson, SC.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1944 - 1995.

Susceptibility of Upland Cotton Cultivars to Silverleaf Whitefly Under Low Desert Conditions

Five and nine upland cotton cultivars were evaluated for susceptibility to silverleaf whiteflies under low desert growing conditions in Imperial Valley, CA in 1994 and 1995, respectively. Results showed that all cultivars were susceptible to whitefly colonization. Cotton lint from all cultivars was sticky and yields were low when whiteflies were not controlled. When whiteflies were controlled initiating treatments at a threshold of 4.1 adults/leaf, DPL 50 and 5415 required 4 applications of insecticides while other cultivars required from 5 to 7 applications during the season. Results indicate that selection of cultivars that are less susceptible to whiteflies can reduce insecticide application and cost of cotton production.

Investigator's Name(s): Peter B. Goodell.

Affiliation & Location: Cooperative Extension, University of California, Kearney Agricultural Center, 9240 So. Riverbend, Parlier CA 93648.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: January-December 1995

Extension Efforts in National Whitefly Outreach and Delivery

This report provides an overview of efforts from numerous agencies and individuals to ensure communication among whitefly workers and dissemination of useful information about whitefly. The following list is not intended to be exhaustive but to provide direction in locating new information sources on this insect.

General Publications:

Flint, M.L., 1995. Whiteflies in California: A Resource for Cooperative Extension. UCIPM Publication 19. University of California, Statewide IPM Project. 53 pp. *Available from P.B. Goodell, 209 891-2500, pbgoodell@uckac.edu*

De Barro, P.J. 1995. *Bemisia tabaci* biotype B: a review of its history, distribution, and control. Division of Entomology Technical Paper 33. CSIRO, Australia. *Available from P.J. De Barro, CSIRO Division of Entomology, GPO Box 1700, Canberra ACT 2601, pauld@ento.csiro.au*

INTERNET Resources:

Silverleaf Whitefly Page - http://WWW.UCKAC.EDU/whitefly/index.htm
Part of UC Kearney Agricultural Center web site - http://WWW.UCKAC.EDU/

Whitefly Management Guidelines - Located under Pest Management Guidelines of a specific crop at the UC IPM web site - HTTP://WWW.IPM.UCDAVIS.EDU/

Whitefly Knowledgebase from Florida and USDA:
http://WWW.IFAS.UFL.EDU/~ENT2/WFLY/INDEX.HTML
This adaptation of John Fasulo's Whitefly Knowledge Base is an excellent resource for whitefly information.

Biological Control of Pest Research Unit - http://rsru2.tamu.edu/bcpru/bcpru.htm
Current information on BC efforts against whitefly pests

University of Arizona Whitefly Research - http://gears.tucson.ars.ag.gov/wcrl/wwghome.html
Provides overview of the research activities of the Whitefly Working Group at Arizona.

List Servers and Use Groups

Whitefly List Server - UC KAC - Service provided to link together those interested in whitefly issues. There are currently 41 subscribers to this unmoderated list server.
To subscribe to the Whitefly mailing list send an e-mail message to Maiser@uckac.edu. In the body of the message type:SUBSCRIBE Whitefly <your first name> <your last name>.
Please turn off the automatic signature generation of your e-mail program.

A use group has been proposed which will help disseminate discussion, news, and queries concerning the study of homoptera. The idea behind this newsgroup is the need to improve fast and informal communication between researchers working on homoptera. The group is being organized and if sufficient interest is voiced, will become reality early in 1996. The proposed name of the group is sci.bio.entomology.homoptera

Investigator's Name(s): Raúl León López, Max Cervantes, Benjamín Sánchez, and Francisco Hoyos.

Affiliation & Location: INIFAP & SANIDAD VEGETAL-SAGAR, Mexicali, B.C. México.

Research & Implementation Area: Section F: Integrated Techniques, Approaches, and Philosophies.

Dates Covered by the Report: 1995.

IPM Actions and Practices in Cotton (2nd. Year)

In the Mexicali Valley and the San Luis Río Colorado Region the average yield of 19,600 hectareas was only 2.22 bales/ha in 1992 because of the SLWF damage. In 1993 the yield was 4.6 bales/ha in 653 hectareas; in 1994 was 5.2 bales/ha in 12,500 has; and in 1995 was 4.9 bales/ha in 35,500 has with only 3.5 insecticide applications/ha. For 1996, growers are expecting to plant 40 to 45 thousands hectareas, because of the market price of the fiber and the confidence they feel in controlling the whitefly and other insect cotton pests based on the results of the last two cotton growing seasons.

The most important IPM actions and practices involved in their result have been:

1. Shredding and plowdown of spring of melon, squash and watermelon immediately after harvest to reduce the dispersion of SLWF adults to cotton fields.

2. Cotton planting date from February 15 to March 31. Still we need to continue persuading the growers to completely eliminate late plantings. We had some in April and May.

3. Another important management practice was defoliation by 2-3 weeks after the last irrigation. However, in 1995 only 60-70% of the hectareas planted to cotton were defoliated. More needs to be done to improve the results with this practice in the future.

4. And maybe chemical control has been at this time the most effective practice to reduce SLWF infestations during the cotton season. Danitol+Orthene and Hostathion+Orthene have been the most effective insecticide combinations.

To assist the PCA in making decisions regarding insecticide use, a regional monitoring of adult SLWF populations in 60 commercial cotton fields was made according with the sampling plan reported by Peter Ellsworth et. al., IPM series Number 2, Cooperative Extension, University of Arizona. From this monitoring we concluded that:

1. In the Mexicali Valley the adult infestation was 3 times higher in 1995 than in 1995.

2. Also in the Mexicali Valley the infestation was almost 5 times higher than in the San Luis Rio Colorado Region during 1995.

TABLE F. Summary of Research Progress in Relation to Year 4 Goals of the 5-Year Plan.

Research Approaches	Goals Statement	Progress Achieved: Yes	Progress Achieved: No	Significance
F.1 Risk Assessment.	Yr. 4: Technology transfer to existing institutional responsibility.			
F.2 Spatial Analysis and GIS.	Yr. 4: Transfer technology to existing institutional programs. Combine GIS data bases.			
F.3 Ecosystem modeling.	Yr. 4: Use model with spatial analysis capability.			
F.4 Networks.	Yr. 4: Continue to operate system. Continue transfer of GIS to extension.			
F.5 Integrated Extension Programs.	Yr. 4: Maintain system.			

APPENDIX A.

5-YEAR NATIONAL RESEARCH AND ACTION PLAN PRIORITY TABLES

TABLE A. Ecology, Population Dynamics, and Dispersal[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
A.1 Define biology, phenology, and demography of SPW on greenhouse, field crop and wild host plants.	Systematic study of SPW on cultivated and weed hosts, seasonal time of occurrence, habitat.	Identify preferred hosts, determine seasonal distribution, determine developmental, reproductive and mortality rates of SPW on crop and weed hosts.	Continue demographic studies, determine relationships between crop sequencing, preferred hosts and population dynamics.	Determine seasonal contribution of cultivated and wild host plants to SPW population dynamics.	Describe role of cultivated and wild host plants on the population dynamics of SPW, identify weak links in seasonal biology.
A.2 Develop efficient SPW sampling plans for research and decision making purposes	Determine spatial distributions, define sample units for immature and adult SPW, examine variance components, optimize sample number and allocation.	Formulate sampling plans, determine relationship between sampling techniques for adults and crop infestations, evaluate feasibility of a standard sampling technique.	Continue development and refinement of sampling plan, implement and test protocols, develop remote sensing tools to estimate regional population levels.	Continue testing and implementation of sampling plans in terms of reliability and efficiency, continue development of remote sensing tools.	Finalize sampling protocols.
A.3 Develop economic thresholds for SPW in relation to feeding damage, honeydew production and virus transmission.	Determine components of yield and quality affected by SPW feeding, virus transmission and honeydew production on crop studied.	Determine and quantify relationships between SPW population density and plant yield and quality, formulate economic thresholds in relation to sampling protocols.	Continue quantification of relationships between SPW density and yields and quality, continue formulation of economic thresholds with refined sampling protocols.	Perform economic analyses, evaluate economic thresholds in crops studied.	Continue economic analyses.
A.4 Develop and test population models to describe and predict SPW dynamics.	Determine model goals, define preliminary model structures and identify data needs, evaluate existing biological information.	Develop relationships between SPW biology and crop phenology and crop sequencing. Integrate SPW, natural enemy, and plant components into simulation models.	Continue model construction, evaluate data needs, begin evaluation of model predictions of SPW population development.	Validate simulation models under field conditions, analyze model behavior.	Identify existing information gaps in insect and plant interactions.
A.5 Determine factors influencing SPW dispersal.	Determine relationships between crop phenology, crop status and SPW dispersal.	Determine biological factors (physiology, behavior, sex, etc.) influencing dispersal.	Determine effects of weather parameters on dispersal.	Examine interrelationships of crop production methods and SPW dispersal.	Summarize information on research progress on SPW dispersal and propose needed research.

A.6 Determine impact of dispersal on population dynamics in greenhouse, field crop, and weed host systems.	Develop marking methods (immunological, rubidium, genetical), determine population development and phenology on various crops.	Conduct mark-release studies-recapture studies, quantify seasonal inter-crop and weed movement, determine influence of host sequencing and spatial patterning on SPW population development.	Continue quantification of SPW movement and determination of host sequencing and spatial patterning, integrate information into population models.	Continue as in Year 3.	Exploit potential of information developed on managing SPW dispersal as a control methodology.

1 Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE B. Fundamental Research - Behavior, Biochemistry, Biotypes, Morphology, Physiology, Systematics, Virus Diseases, and Virus Vector Interactions[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
B.1 Studies of feeding behavior: sensory receptors, ultrastructure, morphology, digestive physiology; intra- and interspecific competition.	Begin studies of ultrastructure, morphology; analyze feeding and digestive processes; begin studies of parameters influencing competition.	Continue studies from Year 1; characterize feeding by-products and digestive enzymes; determine influence of host plant morphology, physiology, ecology and phenology on SPW feeding behavior and competition.	Continue in-depth studies begun earlier; investigate relationship between endosymbionts and nutrition; use feeding monitor to screen for host resistance and response to residues of pesticides and natural products.	Continue research begun earlier; identify weak links for management-based research.	Continue basic research; investigate approaches for interrupting feeding and digestion, and reducing competitive abilities.
B.2 Studies of biochemistry, physiology, nutrition, development and reproduction, genetics and genetic diversity.	Identify temperature tolerances; begin study of host influences (i.e., water balance, osmotic concentrations, nutrients) on SPW; begin studies of nutritional physiology, reproductive physiology, ploidy level.	Continue fundamental studies begun in Year 1; expand studies of genetic diversity; identify areas for continued emphasis.	Continue basic studies; identify potential weak links for further research: i.e., genetic and physiological bases for host selection, habituation, switching, etc.	Continue basic studies; investigate approaches for interrupting or altering key biological processes.	Continue basic studies; implement strategies for interfering with key processes; assess potential for further development.
B.3 Studies to discover and analyze diagnostic characteristics of SPW, including component taxa, and to determine biological and genetic basis for development of biotypes, host races, and species.	Collect SPW taxa and characterize their validity using morphological, molecular, biochemical, and biological studies to distinguish genetically different populations; develop voucher protocol for preservation of morphological and molecular information; establish centralized molecular services.	Continue systematic analysis of SPW; provide molecular services based on information derived from Year 1.	Continue systematic analysis of SPW; develop rapid identification systems.	Finish analysis of SPW character development of rapid identification system.	Provide synthesis of diagnostic analysis of SPW taxa; relate results to other fundamental approaches; continue molecular identification services; finish development of rapid identification system.
B.4 Develop systematic analysis of the genus *Bemisia* utilizing various methods.	Begin analysis of all species of *Bemisia* using at least morphological and DNA sequence analyses; develop collecting and preservation protocols; identify sources worldwide and begin collecting material for analysis.	Continue analyses of *Bemisia* species, defining characters using characters from morphological and DNA sequence studies; investigate value of supplementary methods (i.e., cuticular hydrocarbons, immunological assays, isozymes, symbiont associations, etc.)	Continue analyses of *Bemisia* species, define taxa and begin phylogenetic analysis.	Complete systematic analysis of *Bemisia* species; complete phylogenetic analysis of at least morphological and DNA sequence information.	Complete systematic analyses; validate supplementary methodologies.

B.5 Identify and define SPW toxicogenic effects. Develop dsRNA and cDNA probe.	Characterize toxicogenic effects, cytology and EM.	Fractionate SPW and affected plants. Isolate toxicogenic fractions. Characterize endogenous mediators, Use cDNA probe to screen biotypes.	Define affected plant target molecules and molecules mediating systemic response. Use probe to localize source of dsRNA.	Characterize toxicogenetic molecules and mode of action. Utilize probes for field IDs.	Define mechanisms of plant resistance and integrate knowledge in developing IPM.
B.6 Characterize SPW endosymbiote (SPWe) influence on metabolism, host range, and biotype formation.	Treat SPW with anti-biotics and determine effects on growth, develop-ment and reproduction.	Develop methods for isolation and SPWe and extraction of nucleic acid. Amplify specific SPWe genes via PCR.	Analyze variability of SPWe genome in different SPW biotypes via RFLP, PFE and hybridization with SPW dsRNA probe	Determine specific genes and gene products associated with SPW metabolism.	Analyze progress and determine feasibility of pest management based on interruption of endosymbiotic relation.
B.7 Investigate etiology of diseases; biological and molecular characterization of causal agents; develop understanding of relationship; molecular probes for viral diseases; diagnostics and resistance; virus-vector specificity and interactions.	Collect and establish pure cultures; initiate transmission studies and biological characterizations, cloning and purification for these studies and antibody production, screening for resistance.	Continue with biological and molecular studies; continue cloning and characterization; begin antibody production. Develop detection and identification systems. Study virus-vector interactions: receptors, transmission, transformation, resistance.	Continue developing virus diagnostics; molecular comparisons of sequence data, relations; continue cloning and characterization; continue virus-vector studies. Develop diagnostic tests for epidemiological purposes; clones for (injured) resistance.	Develop strategies for engineered resistance; prototype isolates based upon molecular characterization and distribution studies; biological, molecular parameters, viral designations standardized; methods for identification; mechanisms of vector transmission.	Continue virus-vector studies; evaluate resistance studies: engineered and classified w/prototype isolates. Continue bio-logical and molecular studies of new pathogens; viral taxonomy; standard-ize names.
B.8 Study epidemiological parameters: vector population dynamics; disease thresholds; identify sources of inoculum, distribution, severity, and prevalence of pathogens. Correlate efficiency of transmission with biotypes, diversity and parameters of cropping systems.	Initiate study of transmission efficiency, vector population dynamics, fecundity studies, host reservoir studies. Survey problem areas to identify key virus isolates; develop transmission thresholds for viruses.	Continue to investigate epidemiological parameters; begin to establish diagnostics; identify key isolates for in-depth characterization; study vector-host plant interactions.	Continue epidemiology studies; evaluate strategic management methods (i.e., sanitation programs based on inoculum sources); study vector-host-virus interactions in field; apply diagnostics.	Continue application of diagnostics to field epidemiology studies. Evaluate distribution, reservoirs using diagnostics; evaluate resistance in field studies.	Continue development, application of management strategies based on epidemiology studies. Transfer information for use in cropping systems, host free periods, recommenda-tions for long term disease management
B.9 Study mating and oviposition behavior.	Study mating behavior in detail; determine possible role of sex pheromone; study role of mating in oviposition.	Determine factors, environmental and biological, that affect mating; determine factors affecting oviposition site selection and fecundity.	Develop methods for determining mating success, sperm transfer, fertilization, etc.; determine role of nutrition in oviposition and viability.	Identify factors that may be manipulated to manage or present mating; examine potential of attracticides and manipu-lation of crop production in reducing oviposition.	Exploit such factors in field trials to determine their potential in control methodology; quantify role of oviposition behavior in population dynamics.

B.10 Determine factors influencing host plant selection and host acceptance.	Determine nature of physical, environmental, plant host, physiological cues involved; investigate extent of semiochemical mediation in host finding.	Isolate, identify chemicals and other cues involved; continue studies of host selection and acceptance.	Develop bioassay methodology for quantifying semiochemical effects on SPW behavior.	Determine interactions of semiochemicals with environmental factors, incl. natural enemies.	Determine potential for manipulating semiochemicals and other host-finding or acceptance cues as behavioral components in SPW control systems.
B.11 Identify plant nutritional and defensive responses to SPW and their effects on SPW and natural enemies.	Identify proteins, enzymes, and natural products induced in plants by SPW; examine influence of changes in nutrient levels on SPW and enemies.	Isolate and characterize induced protein, enzymes, or compounds.	Determine effects on SPW and evaluate as resistance mechanism; evaluate effects on SPW natural enemies.	Identify source of defensive factors in plants and their targets in SPW; continue studies of tritophic level interactions.	Target specific factors for genetic engineering of plant resistance.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE C. Chemical Control, Biorationals and Pesticide Application Technology.[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
C.1 Identify, for registration, new chemicals and formulations that effectively control SPW.	Lab and field evaluation of chemicals with rates, combinations to identify promising materials.	Expand field research with best combinations and application methodology.	Evaluate new chemicals in relation to stage of insect killed, economic threshold, and effect on beneficials.	Determine chemical effects of SPW populations, increased yields, and quality of crops to provide data useful for registration purposes.	Formulate control strategy based on research progress that indicates rates, gal/ acre, frequency of applica-tion, and associated secondary pests.
C.2 Identify, for registration, biorational materials with new modes of action.	Initiate studies with oils, soaps, natural products, both organic and inorganic, to determine efficacy.	Conduct field studies to determine coverage, rates, gal/acre, etc., to provide data useful for registration purposes.	Expand studies with best materials with highest potential. Evaluate efficacy, timing, alternatives with other chemicals.	Develop alternating sequences between chemicals and biorationals for best SPW management system.	Implement alternating sequence management systems to prevent resistance.
C.3 Develop application schedules, methods in relation to economic thresholds.	Determine SPW population levels under various chemical and biorational control systems.	Determine relationship between SPW populations, chemical control, and yield for economic threshold.	Identify specific optimum controls in relation to SPW economic threshold.	Validate estimated economic threshold concept and insecticide use patterns.	Develop protocols for SPW economic thresholds and insecti-cide use on as-needed basis.
C.4 Insecticide resistance studies.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Develop standardized insecticide resistance monitoring systems.	Determine insecticide dose relationships, discriminating doses, and hormoligosis.	Initiate study to determine mode of action of insecticides.	Initiate studies to develop insecticide resistance management and outline area-wide pesticide rotation systems.
C.5 Genetics of insecticide resistance in SPW.	Collect strains in different locations, crops, etc., and establish resistance patterns and levels.	Begin construction of isogenic resistant and susceptible strains through back-crossing and selection.	Use RAPD and restriction mapping techniques to ID markers associated with resistance genes.	Isolate individual resistance genes in back-crossed lines and determine cross-resistance relationships.	Initiate studies to develop insecticide resistance management and outline areawide pesticide rotation systems.

C.6 Develop methods for application or delivery of materials to improve control.	Compare methods of application, e.g., aerial, ground, high volume air, and others for estimates of plant (especially under-leaf) coverage. Determine spray deposition (µg a.i./cm^2) and coverage for different application techniques, e.g., aerial, ground, electrostatics, chemiga-tion, air carrier sprays, etc. Relate efficacy to spray deposition and coverage.	Evaluate modified spray equipment, boom drops, nozzles, and arrangements; and chemigation.	Determine efficacy, with best coverage application equipment.	Verify best of the current state-of-the-art application equipment.	Determine need for continued research.
C.7 Evaluate application methodologies for impact on natural enemies and SPW interactions.	Determine baseline information on existing natural enemies-quality and quantity.	Determine effect of various chemicals and biorationals on natural enemy populations and associated minor pests.	Compare rates, combinations, application technology on natural enemy populations.	Determine optimum and best materials and application technology to develop maximum natural enemy conservation.	Develop standard protocols for chemical control and natural enemy integrated systems for best control in relation to economic thresholds.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE D. Biocontrol[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
D.1 Determine effects of indigenous natural enemies on regulating SPW populations.	Survey for and identify key natural enemies in various habitats and seasons.	Continue survey; culture and study reproductive biology of beneficial species.	Continue biological studies; determine effectiveness of species under various habitat and weather conditions.	Determine interactions among SPW, host plants and natural enemies.	Examine species and methods for exploiting selected natural enemies in crop systems.
D.2 Develop methods for enhancing habitats with refuge plantings to conserve natural enemies..	Establish refuge plantings; colonize parasitoids; sample for and identify native natural enemies.	Continue sampling; test inoculative parasitoid releases; determine SPW/ parasitoid interactions.	Evaluate refuge plantings as field insectaries on larger scale.	Continue evaluation of most promising methods.	Implement and evaluate large scale conservation management systems.
D.3 Identify new natural enemies in areas of SPW origin; foreign exploration, importation and release.	Collect, identify and import exotic natural enemies from specific habitats.	Continue collections; assess biology and host relations; develop rearing techniques.	Continue collections; determine habitat "fit" for each candidate; assess interactions with native species.	Conduct host range tests; rear, release promising natural enemies.	Determine adaptation of introductions and effects on SPW populations.
D.4 Determine natural enemy host selection processes and mechanisms.	Study mechanisms involved in natural enemy host foraging.	Study efficiency of host foraging mechanisms.	Determine factors affecting interactions of host foraging mechanisms, hosts and host plants.	Determine potential of implementing host foraging mechanisms in SPW population management.	Implement methodology developed into SPW management systems.
D.5 Inoculate/augment parasite and predator populations through propagation and release.	Identify best candidates for augmentation based on selected attributes.	Develop laboratory rearing procedures for select species.	Conduct tests on technical feasibility of inoculating/ augmenting predator/ parasite populations for suppression of SPW.	Develop mass propagation and release procedures for selected species.	Conduct areawide suppression trials and continue developing the mass propagation, distribution, storage and release technology.
D.6 Determine effects of pathogens on regulating SPW populations.	Determine role in specific crops; develop culturing techniques.	Screen candidates for efficacy and effects on non-target organisms.	Evaluate for efficacy and persistence in small plots; develop formulations, evaluate for micotoxins.	Monitor dispersal and begin large scale field evaluations. Evaluate persistence and develop protocols for suppression of SPW populations.	Expand field evaluations and begin technology transfer.
D.7 Evaluate compatibility of pesticides with SPW natural enemies.	Laboratory screening for effect of pesticides on selected SPW natural enemies and develop baseline data.	Survey for geographic variation to pesticide exposure and select natural enemies with pesticide tolerance; identify pesticides that are compatible with natural enemies.	Challenge selected natural enemies to develop resistant strains.	Limited field trials to determine effectiveness and survival of resistant natural enemy strains.	Evaluate potential in large scale field trials.

D.8 Systematics of predators, parasites and pathogens.	Finalize taxonomist network; inventory species, literature, collections; survey NA fauna and flora; establish common curation techniques.	Continue survey; identify and voucher exotic material; implement protocols.	Review critical genera; establish limits of relevant species worldwide.	Describe new taxa, prepare keys, characterize phylogenetic relationships.	Conduct molecular, biochemical, or other studies on target taxa.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE E. Crop Management Systems and Host Plant Resistance[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
E.1 Determine effect of traditional crop production inputs on SPW population development.	Investigate effects of irrigation, fertilization, and plant growth characteristics on SPW population dynamics.	Identify crop production methodology that may be a factor in SPW population development.	Determine mechanisms involved in crop production factors which greatly affect SPW biology, behavior, etc.	Determine possibility of exploiting or manipulating crop production methods as a factor in SPW management.	Develop methods that are grower acceptable to minimize SPW damage and maximize profits.
E.2 Determine temporal and spatial effects of host plants on SPW populations and dispersion.	Determine SPW reproduction, population development and factors affecting them on selected major crops and weeds.	Identify preferred cultivated and weed hosts and contribution to overall population density and SPW dispersion.	Determine interactions of cultivated host sequences and weeds on SPW population development and movement.	Determine potential of manipulating cultivated host sequences during growing season to reduce SPW populations.	Develop best strategy for cultivated host sequences that will minimize SPW damage to crops.
E.3 Determine effect of colored mulches, trap crops, intercropping, row covers, and other innovative cultural practices as potential SPW control methods.	Identify cultural practices in crop production systems affecting SPW biology and behavior.	Determine potential effectiveness of innovative cultural practices on SPW behavior.	Conduct studies to determine potential of cultural practices to affect SPW population development in the field and affect yield.	Identify cultural factors with greatest potential for adversely affecting SPW population development and improve yield.	Incorporate best potential factors into system and determine effect on SPW and crop net returns.
E.4 Develop reproducible evaluation techniques to isolate resistant germplasm.	Determine rapid, reproducible evaluation techniques for identifying resistance germplasms.	Apply developed methodology to identify resistant germplasm.	Use improved evaluation techniques to identify resistance mechanisms.	Begin to characterize resistance mechanisms and to identify chemical/ morphological components.	Continue characterization of resistance mechanisms
E.5 Identify resistant germplasm to SPW and associated viruses and plant disorders.	Collect potential sources of resistance germplasm.	Screen and identify resistance sources.	Quantify effects of resistance characters on SPW, virus, and associated plant disorders.	Determine interaction of selected plant types and SPW populations in the field.	Continue evaluation of selected plant types for management of SPW.
E.6 Conduct plant breeding studies to select SPW resistant plant germplasm.	Conduct plant breeding studies to incorporate resistance into acceptable plant types.	Continue plant breeding experiments to produce highest resistance levels.	Begin to transfer resistance factors into improved plant types.	Continue the transfer program.	Continue the transfer program.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.

TABLE F. Integrating Techniques, Approaches and Philosophies.[1]

Research Approaches	Year 1	Year 2	Year 3	Year 4	Year 5
F.1 Risk Assessment.	Identify a national evaluation panel to characterize risk assessment information needed for producers and the environment. Design risk assessment procedures for whitefly virus.	Interface with objectives for spatial analysis, network activity, ecosystem models and design risk assessment procedures for whitefly.	Operate risk assessment system. Validate risk assessment estimates. Expand to other pests. Collate multi-location results. Interface with IPM programs and crop loss assessment.	Technology transfer to existing institutional responsibility.	Support risk assessment system and develop management procedures.
F.2 Spatial Analysis and GIS.	Establish a national center to coordinate a national network of spatial analysis with GIS capabilities. Determine information needs for SPW.	Establish a network of user-information coupling participants. Input of spatial data. Look at other pest problems.	Run and validate system performance. Interface system with ecosystem modeling activity. Interface system with existing IPM networks.	Transfer technology to existing institutional programs. Combine GIS data bases.	Operate system under new framework of administration. Troubleshoot activities.
F.3 Ecosystem modeling.	Establish a National ecosystem model panel to identify scale and attributes of components. Interface with network.	Develop site-specific models in all participating states site-specific models. Define appropriate resolution of modeling activity. Address other pest problems.	Interface with spatial analysis. Couple crop model with spatial data.	Use model with spatial analysis capability.	Transfer activity to state institutions and assist in specific activity.
F.4 Networks.	Test and run NBCI bulletin board. Expand network to international dimension for biological control information exhibition. Expand written materials and workshop presentations. Bring GIS up on networks.	Teleconferences on SPW nationally. Expand to agricultural ecosystem management. Coordinate GIS with networks.	Teleconference SPW program internationally. Begin transfer of GIS to extension applications.	Continue to operate system. Continue transfer of GIS to extension.	Transfer national activities to permanent institution support.

F.5 Integrated Extension Programs.	Identify existing taskforce or action groups and link them into a communication network; written, elec-tronic, radio and confer-ences. Support and expand information network, newsletters, news articles, video conferences. Inter-face with appropriate National and State crop programs.	Develop procedures for data capture at local sites throughout the country and expand to other significant pests. Access spatial data and ecosystems models. Incorporate programs with existing IPM programs.	Maintain system and continue to expand other pests.	Maintain system.	Transfer system to permanent support such as State Department of Agriculture, Cooperative Extension Service, Commodity groups, private groups and troubleshoot system.

[1] Source: USDA. 1992. Conference Report and 5-Year National Research and Action Plan for Development of Management and Control Methodology for the Sweetpotato Whitefly. United States Department of Agriculture, Agricultural Research Service, ARS-107, 165 pp. National Technical Information Service, Springfield, Virginia.